Psychological Monographs

Avoidance Conditioning and Signal Duration—A Study of Secondary Motivation and Reward

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INTRODUCTION

FOR the past quarter of a century much of the theorizing as well as research that has been carried out by American psychologists in the field of learning has been based on the supposition that the conditioned reflex is, as John B. Watson termed it, the "fundamental unit of habit." Since the phenomenon of conditioning has been traditionally linked, from Pavlov on, with the conception of learning through association, or paired presentation of stimuli, this has meant that associationism has been the predominant, if not exclusive, learning doctrine for a large group of workers in this field.

Within recent years, however, it has become increasingly clear that conditioning, on the one hand, is neither basic nor simple, and that associationism, on the other hand, is grossly inadequate as a theoretical interpretation. A decade ago Dunlap (8) commented that conditioning, far from being the prototype of all other learning, is actually "among the most complicated of learning processes" (p. 85), More recently Thorndike (46) has said that "the conditioned reflex is the one type of learning that manages, even more completely than maze learning, to conceal the true nature of the learning process in a mass of special conditions" (p. 113). And experiments by Hunter (25), Brogden, Lipman, and Culler (2), and others on the relative efficacy of the "classical" vs. "instrumental" conditioning procedures (cf. Hilgard and Marquis, 19) have not only further stressed the complexity of conditioning but have also seriously undercut the logic of association theory.

In a series of earlier papers (33-38) evidence has been advanced for believing that learning, in both conditioning and trial-and-error situations is dependent, not upon the mere association, or temporal contiguity, of stimuli (or responses), but rather upon the occurrence of a state of affairs which has been variously designated as goal-attainment, problem-solution, pleasure, success, satisfaction, gratification, adjustment, reestablishment of equilibrium, motivation-reduction, consummation, reward.[1] The Law of Effect, as recently re-formulated by Thorndike (47) and others (23, 37, 40), thus becomes the basic determinant of all learning. The present study represents an application of this point of view in the realm of avoidance conditioning and attempts to resolve certain paradoxes which well established facts in this field constitute for associationism.[2]

ANALYSIS OF A PARADOX

The experiment by Brogden, Lipman, and Culler which has already been cited

[1] For an analysis of other factors in conditioning, see Girden (15), Grether (16), Harris (18), Hull (22), and Mowrer (33, 35).

[2] Some writers have equated associationism, in the sense of Pavlovian stimulus substitutionism, with the stimulus-response "connectionism" of Thorndike. Instead of lumping both Pavlov and Thorndike together as associationists and contrasting them with the Gestalt, or "field theoretical", writers, the line should be drawn with Pavlov on one side and with Thorndike and the field theorists on the other. Insofar as Gestalt psychology has a theory of learning and a concept of reinforcement, the resemblance to the Law of Effect is certainly greater than to the Pavlovian position. The "pleasure-principle" of Freudian psychoanalysis is also far more closely related to the Law of Effect than to stimulus substitutionism.

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serves especially well as a point of departure for showing the fatal defects in associationism. These writers have shown that conditioning is markedly superior in guinea pigs if the conditioned stimulus (a 1,000 cycle tone) is followed by the unconditioned stimulus (electric shock) only when the conditioned response (a short run in a modified activity cage) fails to occur within a stipulated period of time (2 seconds). In other words, these writers report better conditioning, i.e., a higher incidence of anticipatory responses to the "danger signal," in the group of animals in which shock was avoidable than in the group in which it was not.

From a commonsense point of view, this finding is not very surprising. But if considered in the light of traditional conditioning theory, it constitutes a paradox. As Hilgard and Marquis (19) point out, the "classical" conditioning procedure has involved invariable pairing of the conditioned and unconditioned stimulus, on the assumption (derived from association theory) that this would provide maximal facilitation of the conditioning process. Yet the findings of Brogden, Lipman, and Culler show that, at least under the experimental conditions which they employed, an "instrumental" procedure, in which a conditioned response *prevents* pairing, gives decidedly better results than does the "classical" procedure. This breakdown of association theory raises the question as to whether "effect" theory can provide a more satisfactory explanation of the observed facts.

An important consideration which traditional conditioning theory has not ordinarily taken into account is the fact that the so-called unconditioned response is always, in well-designed experiments, more or less heavily rewarded. Thus, in the experiment just cited, the guinea pigs quickly learned to run in response to the electric shock (i.e., to make the so-called unconditioned response) because this action (by revolving the cage the required amount) automatically terminated the shock. And as long as the experimental conditions remained unchanged, running in response to shock would continue to be highly rewarding. This is obviously an instance of simple trial-and-error learning which is readily explicable in terms of "effect" theory.[3]

Fortunately no new principle is needed to account for the development of conditioning in this situation. Since the tone and the shock occur in close temporal proximity, they constitute together the stimulus-compound which produces the running response. Since this response is

[3] Failure to appreciate the importance of the rewarding, or adjustive, function of the unconditioned response has led to much confusion. The bothersome phenomenon of "adaptation" to the unconditioned stimulus, which tends to occur when this stimulus is of *fixed* duration, is a case in point. Culler and his associates (6) have rightly stressed the methodological advantage of making the unconditioned stimulus subject to termination by the unconditioned response, although they have not offered a systematic explanation of this advantage.

(It now appears that we have partially misunderstood the writings of Professor Culler on this score. In correspondence recently received from him, he states that it has been the practice in his laboratories to use an unconditioned stimulus (shock) of "fixed duration, except as it is *terminated by the animal's response*". In other words, the shock lasts for a brief, fixed period (0.1″ or 0.2″) unless the subject makes the appropriate escape response *within this period*. One of the reasons which Professor Culler gives for using a shock of limited duration is that subjects sometimes adjust to a prolonged shock by "freezing" to the grill instead of running, jumping, etc. As pointed out elsewhere (38), this immobilization to shock will not occur if the shock-circuit is suitably designed. Other experimentation now in progress is aimed at empirically testing the relative desirability of using a shock of fixed vs. variable duration in conditioning work. Our results to date support the position adopted above, namely, that, other things being equal, better conditioning results if the shock is always terminated on the basis of what the subject does rather than after any arbitrarily fixed interval.)

rewarded (by shock-reduction) on each occurrence, it becomes more and more strongly connected, not only to the shock, but also to the tone. Since the onset of the tone occurs somewhat in advance of the onset of the shock, there is an opportunity for the response to the tone alone, when this connection becomes sufficiently strong, to occur in advance of the shock. When the running response thus "moves forward" and occurs to the tone alone, it is said to have become "anticipatory" or "conditioned." But the same basic mechanism of reinforcement is responsible for the strengthening of both the connection between the shock and the response (trial-and-error learning) and the connection between the tone and the response (conditioning proper).

Although it is possible, as just indicated, to bring conditioning within the framework of "effect" learning theory,[4] the paradox created by the superiority of the "instrumental" conditioning procedure over the "classical" procedure remains. On the basis of the analysis suggested above, the strengthening of the connection between the tone and the running response is dependent, no less than in association theory, upon the paired presentation of the tone and the shock. Since it is *escape from shock* which reinforces both the response to the tone and the response to the shock, there can obviously be no reinforcement, from this source at least, if the shock does not occur in conjunction with the tone. But, as the findings of Brogden, Lipman, and Culler indicate, a procedure which permits *avoidance of shock* results in better conditioning than does a procedure permitting only escape from shock.[5, 6] Association theory provides no

satisfactory way of accounting for this finding, but by extending the analysis already undertaken in terms of the Law of Effect an explanation is soon forthcoming.

A re-inspection of the results reported by Brogden, Lipman, and Culler reveals that there are really two paradoxes to be accounted for instead of one. Not only must an explanation be found for the fact that the instrumental conditioning procedure showed an over-all superiority to the classical procedure; some way must also be found of accounting for the fact that the animals which were subjected to the classical procedure made as many conditioned responses as did the other group in the beginning; but later, instead of making more and more conditioned responses, they made fewer and fewer. In other words, after an initial period in which the learning curves for both groups rose in a virtually identical manner, the curve for the classical-procedure group continued to rise for a time but more slowly, and then progressively deteriorated, whereas the curve for the instrumental-procedure group mounted steadily to a 100% criterion. See Figure 1.

On the basis of these facts it would seem that with the initial appearance of a conditioned response (through the process of "parasitic" reinforcement[7]),

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[4] Cf. Hull (23).
[5] The expressions *escape from* and *avoidance*

of a noxious stimulus have sometimes been used in conditioning literature as more or less synonymous. In the present paper they are intended to have very distinct connotations. *Escape from shock* will here mean that the shock has impinged upon the subject but is then by some means terminated. *Avoidance of shock*, on the other hand, will mean that, in a situation in which shock might have occurred, it does not.

[6] When Brogden (3), using dogs as subjects, subsequently compared the classical and the instrumental conditioning procedures, he obtained about the same amount of conditioning in both cases. This finding appears to have been due to the circumstance that what was intended to be the classical procedure was actually also instrumental.

[7] "Parasitic" reinforcement is here used to

new factors enter into the situation. It is as if there were one mechanism for bringing the conditioned response into existence, another mechanism for perpetuating it if it is "successful," and yet another mechanism for suppressing it if it is a failure.[8] If the conditioned response serves any "purpose", i.e., if its
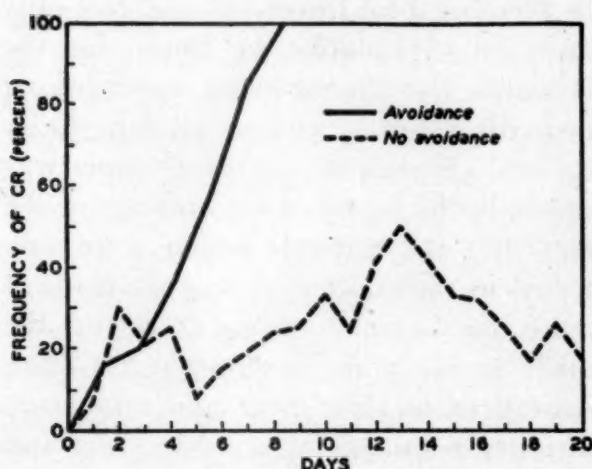

FIG. 1. A comparison of the amounts of conditioning obtained in two groups of guinea pigs, based on the use of the "classical" (no avoidance) and the "instrumental" (avoidance) training procedures. This graph is a slightly modified version (reproduced from Hilgard and Marquis, 19) of curves originally published by Brogden. Lipman, and Culler (2).

occurrence averts (or substantially lessens) the impact of the noxious stimulus, it is perpetuated; but if the response has no such efficacy, it is in some way actively depressed. The problem is to determine precisely how this species of

"reality testing" is so nicely accomplished.[9]

Let us first search for a possible mechanism whereby a conditioned response which proves "useless"—as conditioned responses nearly always do in classical conditioning—may be eliminated. Present evidence indicates that any response, if not in some manner rewarding, will cease to occur if repeatedly elicited.[10] But this fact is of little assistance in the present instance, since the task here is to explain how it is that a conditioned response that is being constantly reinforced "parasitically" may nevertheless disappear.[11] It is not, therefore, a question of accounting for the disappearance of a response in the absence of reinforcement (simple extinction) but rather of discovering some negative factor which operates in the direction of inhibiting or at least depressing the conditioned response, despite continued reinforcement of the kind which brought it into existence.

From a commonsense standpoint it would seem reasonable that if an animal gets "punished" regardless of whether it makes a given response or not, it might as well "take it easy" and not make the response. Or, to speak somewhat more

designate the strengthening of the tone-running (conditioned) sequence through the action of the basic rewarding situation provided by the shock-termination. The strengthening of the shock-running (trial-and-error) sequence may, in contradistinction, be termed "intrinsic" reinforcement.

[8] In order to avoid possible confusion, attention should be called to the fact that in both instrumental and classical conditioning, the procedure is exactly the same (uniform paired presentation of the conditioned and unconditioned stimulus) up to the point that the first conditioned response occurs. The mechanism through which the conditioned response makes its appearance is, therefore, necessarily the same in both cases. Only with the advent of a conditioned response do the procedures and the underlying mechanisms become differentiated.

[9] The expression, "reality testing", as employed clinically, usually refers to situations which are analogous to the omission (extinction) of a conditioned avoidance reaction, "to see if the danger is still there" (cf. French, 12). The type of "reality testing" here referred to is of a different kind, serving to determine whether the conditioned response will "do any good".

[10] One should perhaps say, "any learned response", although even reflexes can often be markedly diminished if repeatedly elicited in circumstances which deprive them of their normal functional utility (32).

[11] This phenomenon, which Wenger (50) and Hovland (20) have termed "inhibition of reinforcement" is not confined to the realm of avoidance conditioning. Pavlov (41) discusses it at length in connection with classical salivary conditioning experiments. The problem in its broader ramifications will be considered in detail later.

precisely, we may say that since, in the classical conditioning procedure, the subject has to make one response to the unconditioned stimulus in any event, an additional response made to the conditioned stimulus is a waste of effort. In other words, a shock and two responses represent a more "punishing" combination than do the shock and a single response. Therefore, not making a response to the conditioned stimulus is from this point of view more economical and efficient than is making one: hence the tendency, when the classical conditioning procedure is followed, for the conditioned response, after making its appearance and proving ineffective, to disappear. As Brogden, Lipman, and Culler point out in connection with their experiment on guinea pigs, "Nothing was to be gained by turning the cage, since the shock came anyway; so when the tone began, they literally 'sat tight,' held the breath, and tensely awaited the shock" (p. 111).[12]

Although perhaps possessing some validity, this explanation is not very rigorous or compelling. A more satisfactory hypothesis is the following.[13] All striped-muscle reactions produce pro-

[12] A little later these writers remark: "One group [of animals] finds a solution by turning the cage [in response to the tone]; the other, faced with an unavoidable shock, so places and tenses the trunk and limbs as to minimize its effects" (pp. 111). This intimation that the classical-procedure group actually reduced the noxiousness of the shock by not responding to the tone seems unjustified. The cage had, in any event, to be turned a certain amount before the shock would go off. This could hardly be done either more promptly or less painfully by refusing to move until the shock actually occurred (cf. footnote 2).

[13] This hypothesis was suggested to the senior author by some informal remarks made by Mrs. Barbara Lyndon. Miller and Dollard (30) have independently evolved a similar theory. The basic idea involved in both cases is inherent in Freud's conception of inhibition as "a restriction which the ego imposes on itself in order not to arouse anxiety" (13, p. 37).

prioceptive, or "backlash," stimulation. If, therefore, a given reaction, such as running, occurs to a noxious (unconditioned) stimulus, the resulting response-produced stimulation *follows* the noxious stimulus and will have no special significance. But if, on the other hand, the same response occurs to the conditioned stimulus in a classical conditioning procedure, then the response-produced stimulation will *precede* the noxious stimulus and will itself become (along with the conditioned stimulus proper) a "danger signal". The occurrence of running as a conditioned response thus becomes "punishing," i.e., arouses anxiety, and the subject is more or less powerfully motivated *not* to engage in this kind of behavior, since not doing so is rewarded through anxiety-reduction (36). Thus a "secondary" (emotional) source of reinforcement tends to inhibit the conditioned running response (by rewarding inaction) even though the mechanism of "parasitic" reinforcement continues to strengthen it. This inference is consistent with the observation that animals in a classical conditioning experiment are in obvious conflict between a tendency to make the conditioned response and a tendency not to make it (3). If, as in the experiment reported by Brogden *et al.*, the tendency not to make the conditioned response eventually dominates, this can only mean that the anxiety-reduction resulting from not making the response is more powerful than is the parasitic reinforcement.

Viewed in this light, the slowness which subjects (both human and infrahuman) have sometimes shown in developing conditioned responses in experimental situations becomes less a reflection upon their intelligence and the efficacy of conditioning as a method than upon the understanding employed in

devising the experimental procedure. The analysis just proposed to account for the conflict necessarily engendered in the classical conditioning procedure has various implications which cannot here be relevantly discussed. The immediate aim has been merely to account for the fact that a conditioned response, after first normally developing, tends, in a classical conditioning procedure, to become erratic and to deteriorate.

The task which now confronts us and the one with the most direct bearing upon the experiment shortly to be reported is to determine what sort of new mechanism, if any, comes into play when circumstances are such that a conditioned response serves to prevent the occurrence of the unconditioned (noxious) stimulus. Under these circumstances the connection between the conditioned stimulus and the response in question can be parasitically (associatively) reinforced only when the response fails to occur to the conditioned stimulus alone and is elicited by the added influence of the unconditioned stimulus. The question is whether there is any other source of reinforcement whereby a conditioned avoidance response may be perpetuated, independently of parasitic reinforcement. In discussing what he has called the "dilemma of the conditioned defense reaction," Hull (21) has formulated this problem as follows:

"For a conditioned defense reaction to be wholly successful, it should take place so early that the organism will completely escape [avoid] injury, i.e., the impact of the nocuous [unconditioned] stimulus. But in case the unconditioned stimulus fails to impinge upon the organism, there will be no [?] reinforcement of the conditioned tendency which means (one would expect) that experimental extinction will set in at once. This will rapidly render the conditioned reflex impotent which, in turn, will expose the organism to the original injury. This will initiate a second cycle substantially like the first which will be followed by another and another indefinitely, a series of successful escapes [avoidances] alternating with a series of injuries. From a biological point of view, the picture is decidedly not an attractive one. . . . The problem presents a fascinating field for experimental investigation" (pp. 510-511).

Viewing the problem again from a commonsense standpoint, one might say that it is rewarding *not* to receive the noxious stimulus which the conditioned stimulus presages and the conditioned response averts. But such a statement is obviously vague and incomplete. In the final analysis reward appears always to involve the elimination (or reduction) of actual stimulation, i.e., a state of discomfort, or motivation. Therefore, *not getting something* can hardly, in and of itself, qualify as rewarding. Not getting "punished," or "injured," is rewarding *only if punishment is expected,* i.e., only if the subject is anxious or fearful, and if this expectation in some way gets *reduced.*[14] In other words, if a conditioned avoidance reaction occurs when the subject is anxious and if the subject then ceases to be anxious (or becomes less so). such a response would be reinforced and might be perpetuated as long as the danger situation served to arouse a state of anxiety in the subject.

We know, of course, that fear, as an "emotional" reaction, is aroused by precisely the same sort of stimuli that produce conditioned avoidance responses, namely, by "danger signals." We have, therefore, good reason for positing that fear is likely to accompany avoidance reactions. We also know that, other things being equal, fear is likely to diminish with the termination of the danger signal. We thus arrive at the deduction that *conditioned avoidance reactions which terminate the conditioned*

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[14] Cf. Hilgard and Marquis (19, pp. 59-60).

stimulus (danger signal) will be reinforced by the resulting diminution of anxiety and will tend to be perpetuated, independently of the mechanism of parasitic reinforcement. Just as the unconditioned reaction serves to reduce or eliminate the unconditioned stimulus (primary motive) and thereby perpetuates itself, the conditioned reaction, if it reduces or eliminates the conditioned stimulus (and thereby the secondary motive of fear), will likewise tend to perpetuate itself.[15]

In a state of nature any overt response which serves to reduce the danger of one organism being attacked by another will ordinarily also eliminate or at least substantially reduce the cues which elicit this response. However, in the conditioned-response laboratory the seemingly universal practice has been to employ conditioned stimuli of arbitrarily fixed duration.[16] If the hypothesis which has just been proposed is correct, one would expect variations in the duration of the conditioned stimulus in relation to the time of the occurrence of the conditioned response to influence the extent to which the conditioned response can survive, without parasitic reinforcement. It is well established that the optimal condition for learning of a trial-and-error nature is one in which the factor of reward, or "success," comes immediately after the occurrence of the "correct" response. If the reward either precedes or follows this response by an appreciable length of time, other responses will be more strongly reinforced, with consequent impairment of the learning of the "correct" one. Since this is true,[17] it follows that if the anxiety which is aroused

by a danger signal terminates either significantly before or after the occurrence of the conditioned avoidance reaction, this reaction will be reinforced less than if the anxiety were to terminate with the occurrence of the avoidance reaction. And since anxiety tends to be coterminous with the danger signal, it further follows that the conditioned avoidance response should be more quickly acquired and better retained if the conditioned stimulus ceases *with* the response than if it ceases either *before* or *after* the response.[18] This inference has been tested in the experiment which will now be reported.

SUBJECTS, APPARATUS, AND PROCEDURE

Laboratory avoidance conditioning in human beings is so likely to be complicated by uncontrolled factors (35, 36) that it seemed desirable to employ animal subjects in the present investigation. Twenty-four rats (Lashley strain), ranging from four to six months of age, were divided into three groups (one male and seven females to the group).

In Group I the procedure was as follows. After a rat had been placed in the apparatus shown in Figure 2,[19] it was allowed to remain unmolested for two minutes. At the end of this time a *buzzer* (ordinary annunciator type), which was mounted on the back of the apparatus, was sounded for one second. Following

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[15] Sheffield (44) has proposed a different analysis of this problem which, in the writers' opinion, fails to take all the facts into account.

[16] Cf. footnote 24.

[17] Cf. Hull's discussion of the "temporal gradient of reinforcement" (24).

[18] A conditioned response is thus seen to be *avoidant* as far as the unconditioned stimulus, or primary motive, is concerned; but in respect to the secondary motive of fear it is an *escape* reaction. Thus, continued successful avoidance of the primary noxious motive is made possible through the reinforcement provided by escape from the secondary motive. In other words, a response which develops on the basis of parasitic reinforcement may be perpetuated by a new form of intrinsic reinforcement which is made possible by the phenomenon of secondary motivation.

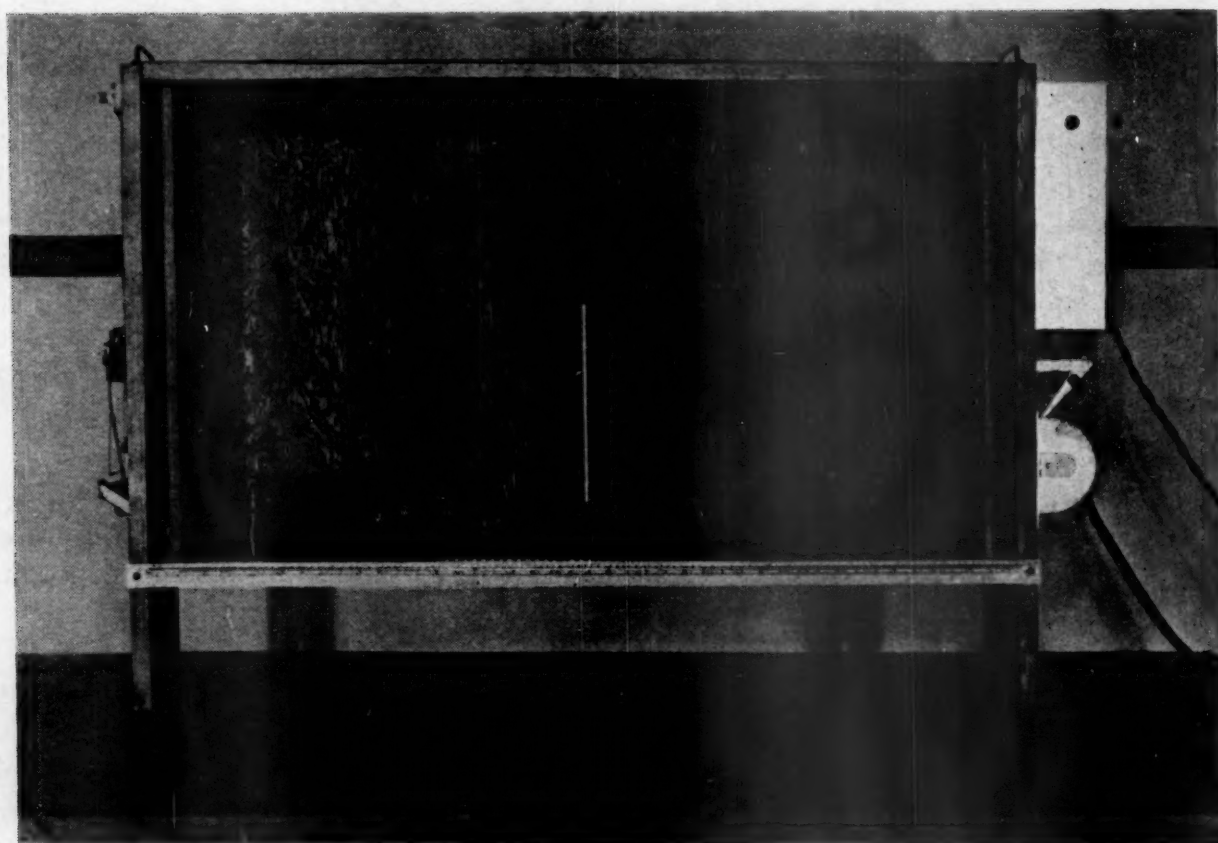[19] This apparatus has been described in detail elsewhere (38).

FIG. 2. Apparatus for conditioning a simple locomotor response in the rat. All experimentation was carried out in a sound-proofed room with the apparatus internally illuminated and with a one-way screen between the rat and the experimenter. The experimenter presented the conditioned and unconditioned stimuli by means of the remote-control box shown in the foreground.

the onset of the buzzer, the rat had five seconds in which to make the response of moving from one half of the grill to the other (the dividing line being indicated by the white stripe on the interior wall of the apparatus). If the rat did not make the required response during this five-second period, an electric charge was applied to and maintained on the rat's half of the grill until the response occurred. (The flow of current was approximately 1.1 milliamperes at 180 volts, with a 350,000 ohm fixed resistance in series with the subject, whose own resistance was usually about 1,000,000 ohms.) The number of "spontaneous" crossings from one half of the grill to the other was recorded, as were the latencies of both the conditioned and the unconditioned responses. The interval between successive trials was always two minutes.[20] All animals received 10 trials a day for 10 days, making 100 trials in all.

The procedure employed with the ani-

[20] This interval may have been unnecessarily long; equally good results might have been obtained with an interval as brief as one minute. Earlier studies (36, 39, 43) indicate, however, that inter-trial intervals of substantially less than one minute result in inferior conditioning. Evidence has likewise shown that the use of a fixed interval between successive trials actually gives less "temporal" conditioning, i.e., fewer "spontaneous" responses between stimulus presentations, than does the use of a variable inter-trial interval. If, for example, in trying to avoid temporal conditioning, the policy be adopted of withholding stimulation until the animal has been *quiet* for a certain period, then inactivity is the state which always precedes stimulation and thus becomes "dangerous". If, on the other hand, the stimulation comes on a fixed schedule, regardless of whether the animal has just been quiet or active, then quietness is not specifically penalized and activity is not unduly encouraged. As the results which are reported later clearly show, the amount of "spontaneous", or "interval", activity which occurred in this experiment was remarkably small.

mals in Group II was exactly the same as the Group-I procedure save for the fact that the buzzer was of variable rather than of fixed duration. In Group II the buzzer came on and stayed on in all cases until the rat made the required response, regardless of whether this response occurred within the initial five-second period, to the buzzer alone, or had to be forced by means of the shock.

of the Group-I animals a conditioned response occurred less than one second after the onset of the buzzer, the buzzer did not, of course, terminate *before* the conditioned response occurred; but since the conditioned response usually had a latency of over one second, this was not a serious consideration.)

It will be noted that in all three groups the so-called instrumental conditioning

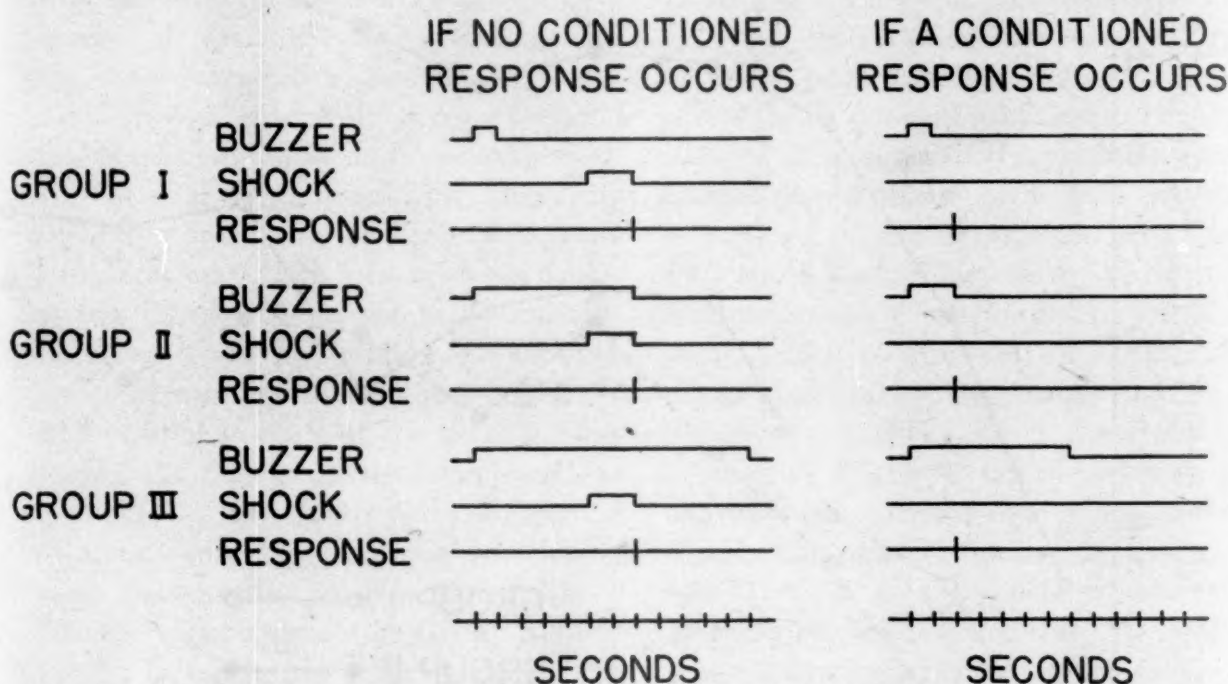|		IF NO CONDITIONED RESPONSE OCCURS	IF A CONDITIONED RESPONSE OCCURS
GROUP I	BUZZER SHOCK RESPONSE		
GROUP II	BUZZER SHOCK RESPONSE		
GROUP III	BUZZER SHOCK RESPONSE		
		SECONDS	SECONDS

Fig. 3. Schematic representation of the three procedures used in this investigation.

In both instances the buzzer ceased the moment that the response occurred.

The animals in Group III were also treated exactly as were those in Groups I and II except as regards buzzer-duration. In their case the buzzer always lasted for five seconds after the crossing response occurred, regardless of whether this was on a conditioned or unconditioned basis.

There were thus provided for Groups I, II, and III conditions in which the conditioned stimulus terminated, respectively, *before, with,* and *after* the crossing response, irrespective of whether it occurred as a conditioned or as an unconditioned response. (If, in the case

procedure was employed, i.e., the unconditioned stimulus (shock) was in all cases avoided if the crossing response occurred within the prescribed five-second period after the onset of the conditioned stimulus (buzzer); and if the unconditioned stimulus was not thus avoided, it lasted only until the rat made the appropriate escape reaction.

In order to avoid possible ambiguity concerning the three procedures just described, they are schematically represented in Figure 3. Here the response, when elicited by shock, is represented as always occurring after an interval of two seconds (i.e., seven seconds after buzzer onset). It will be understood, of course,

that this interval was actually subject to considerable variation, being frequently either longer or shorter than the arbitrarily selected two seconds. The latency of the response when elicited by the buzzer alone is also arbitrarily represented as being two seconds. Here there was likewise much variability. But these oversimplifications, if kept in mind, will not

taneous" responses, and latency of both conditioned and unconditioned responses. These items will be presented and statistically analyzed in this order, followed by a brief description of miscellaneous findings.

Number of Conditioned Responses

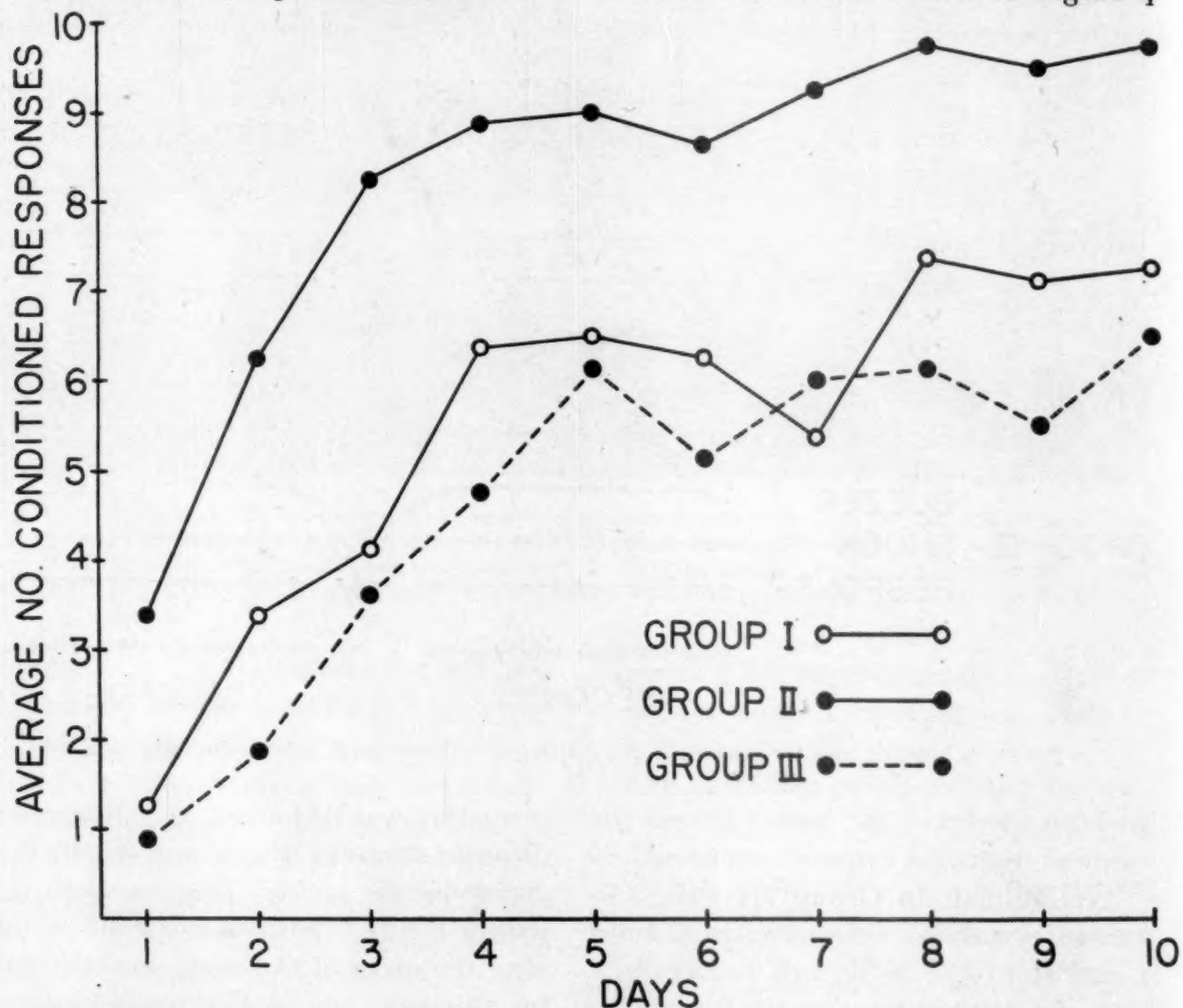The three curves shown in Figure 4

FIG. 4. Average number of conditioned responses made by three groups of rats on each of 10 successive days.

impair the usefulness of Figure 3 as a kind of blueprint of the experiment as a whole.

RESULTS

The data obtained in this study fall into three main categories: number of conditioned responses, number of "spon-

indicate that, whereas the incidence of conditioned responses in Group I was slightly superior to that of Group III, the incidence of such responses in Group II was decidedly superior to that of both Groups I and III. In order to obtain an estimate of the reliability of these differences, the following procedure was

carried out. From Figure 4 two sources of variability in the incidence of conditioned responses are immediately evident: variability between groups and variability between days. Inspection of the original data reveals, moreover, a third source of variability, namely, variability between animals. But since the traditional "critical-ratio" technique of determining the reliability of a difference between two means takes only two sources of variability into account—in this case, variability between animals and between groups—it becomes essential, if this technique is to be employed efficiently, that the variability between days be in some manner eliminated from consideration.[21] This can be done by ignoring the day-to-day scores of individual animals and considering instead only the total number of responses made by each animal in each of the three groups during the course of the experiment, as a whole, i.e., the number of conditioned responses made out of the 100 which were theoretically possible, but unlikely. For the eight animals in Group I these values, in ascending order, were: 31, 39, 49, 51, 57, 61, 74, 78. For the animals in Group II, they were: 64, 74, 79, 80, 86, 91, 93, 94. And for the animals in Group III, they were: 22, 23, 28, 53, 58, 60, 63, 65. (The number of unconditioned responses made by any particular animal during the whole experiment is, of course, 100 minus his conditioned-response score.)

When these data are subjected to treatment according to the critical-ratio method,[22] it is found that the C. R. of the difference between Groups I and II is 4.076, between Groups I and III, 0.973,

and between Groups II and III, 4.761. Since n-1 was used in computing the standard error of the group means, it is legitimate to translate the C. R.'s thus obtained into t-values. When this is done (see Fisher's "Table of t," 11, p. 177), it is found that the differences between the incidence of conditioned responses in Groups I and II and Groups II and III are "significant at the 1% level." According to the logic of the "null hypothesis," this statement means that if the Group-II procedure were not really superior to the Group-I and Group-III procedures, differences of the obtained magnitude would occur only once in 100 repetitions of the experiment. (In fact, a C. R. of 3.499 is significant at the 1% level under the conditions of this experiment, which means that the C. R.'s actually obtained are even more highly reliable, but Fisher's table does not go beyond the 1% level.) On the other hand, the difference in the incidence of conditioned responses obtained in Groups I and III (C. R. = 0.973) is significant only at the 35% level. Since the 5% level is conventionally accepted as the criterion of scientific trustworthiness, this latter difference is not "reliable"; but the other differences—which are the important ones in this experiment—are highly so.

Examination of the conditioning scores listed above shows that the range of these scores is only 30 (64-94) for the Group-II animals, as against 47 (31-78) and 43 (22-65) for the Group-I and Group-III animals, respectively. The standard deviation for the scores of Group I is 16.10, of Group II, 10.42, and of Group III, 18.77. Converting these values into "coefficients of variability,"[23] and thereby correcting for differences due to the absolute values of the three group means, one obtains a V of 29.27 for

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[21] If this were not done, spuriously large standard deviations would be obtained, with the result that the reliability of the differences between groups would be spuriously low.

[22] See Garrett (14), pp. 210-215.
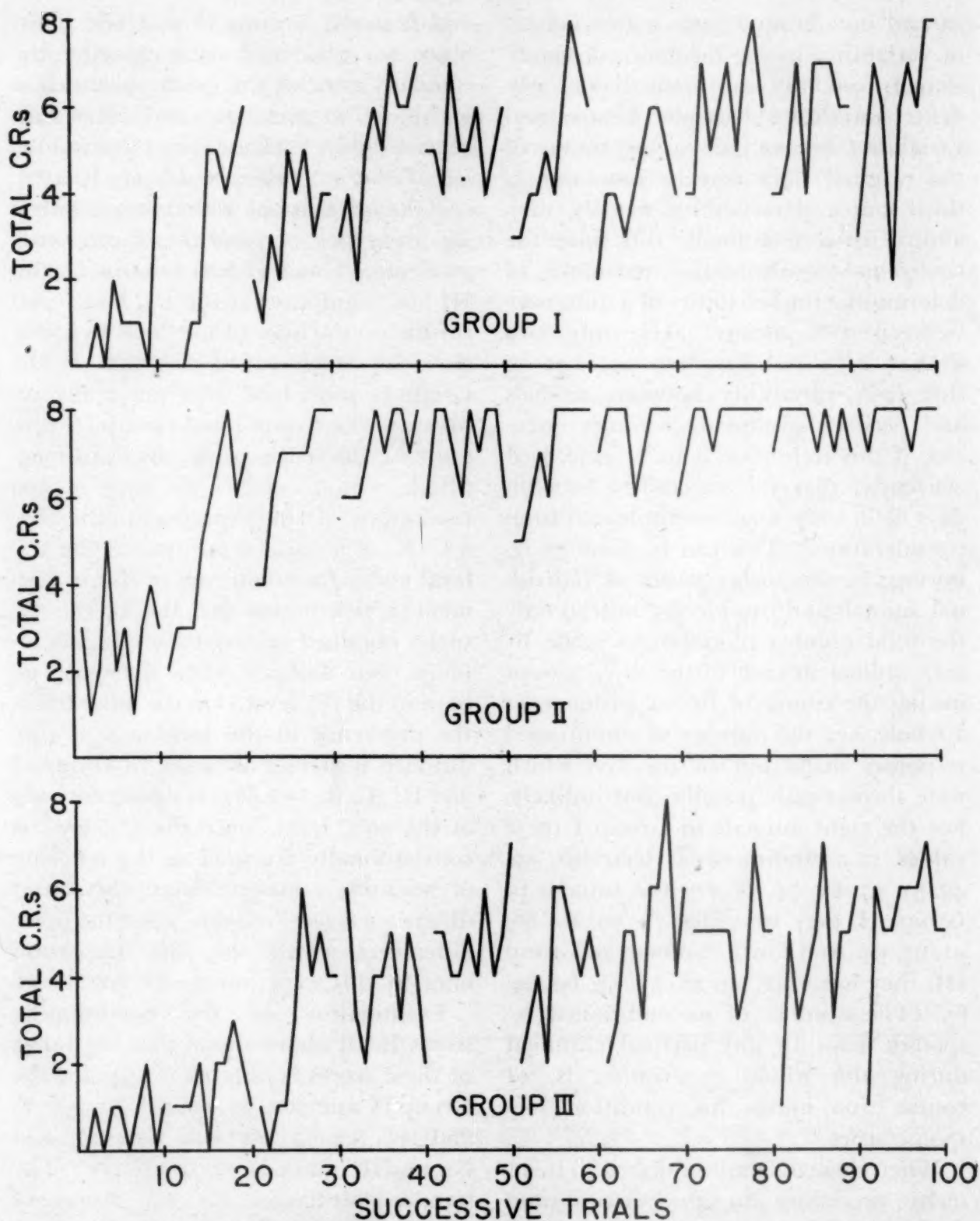
[23] See Finner (10, p. 164).

FIG. 5. Total number of conditioned responses made by all subjects in Groups I, II, and III throughout the experiment. These curves are designed to show the group differences in variability from trial to trial. The discontinuities in the curves separate each day's trials from those of the preceding and following days.

Group I, 12.62 for Group II, and 40.37 for Group III. Such large differences in variability as these suggest that they may

be "reliable," i.e., that the three groups may have actually differed not only in the average incidence of conditioned re-

sponses but also in the magnitude of "individual differences," or "variance within groups."

Determination of the reliability of the difference between two *V*'s is at best a cumbersome procedure and, when small numbers of subjects are involved, is subject to considerable error. However, a convenient and more accurate method of achieving the same end is described by

exceeds 3.79. Although the obtained *F*-values for Groups I and II and for Groups I and III fall considerably below this figure, the *F* for Groups II and III (namely, 3.245) approaches this figure and therefore approximates significance at the conventional level of 5%. This finding supports the suspicion that the three groups of animals employed in this experiment differ significantly in the
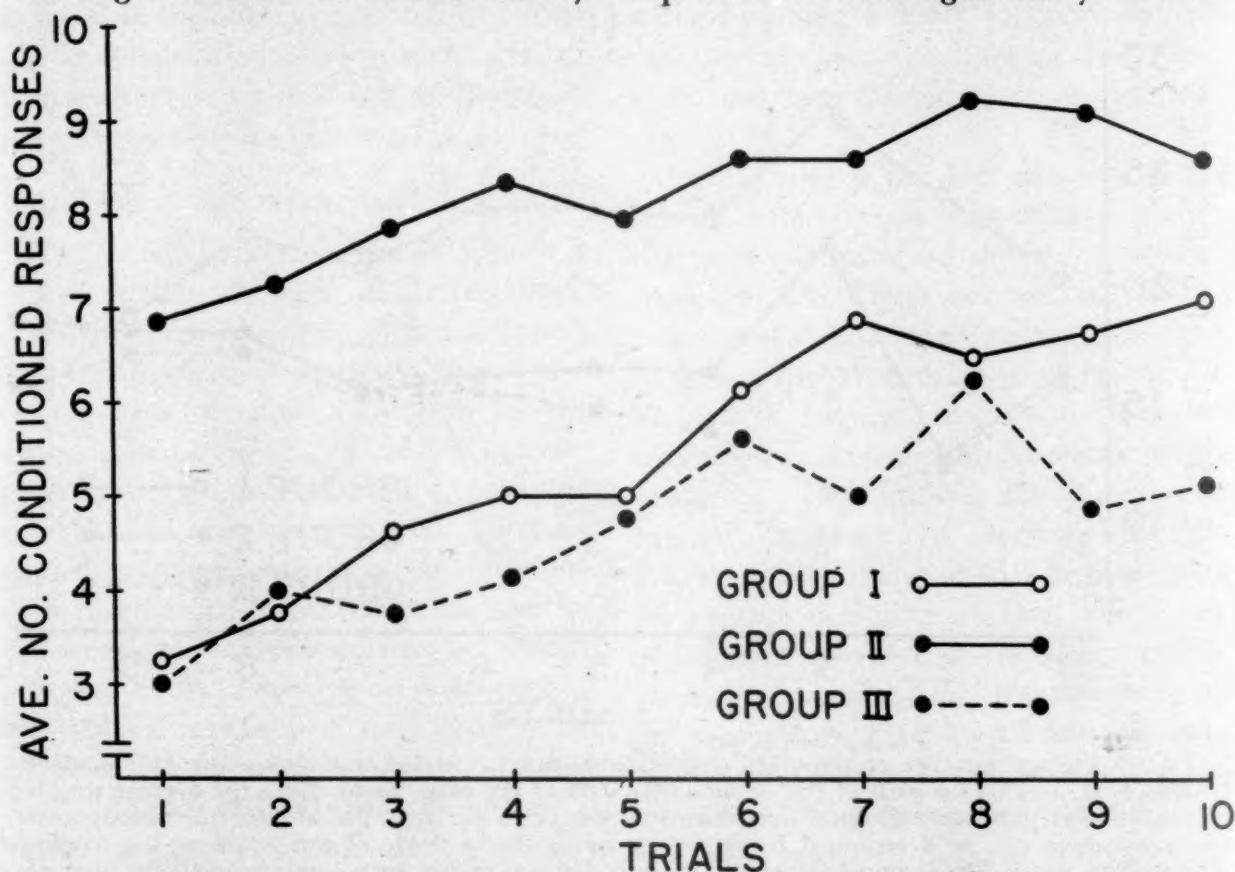

FIG. 6. Average number of conditioned responses made by Groups I, II, and III on trials 1-10 on all 10 days of the experiment.

Lindquist (29, pp. 60-66) and is based on Fisher's z-test (not to be confused with his z-test in relation to correlation, or *r*). Employing this method one finds an *F* of 2.387 for the difference in variability between Groups I and II, an *F* of 1.359 for the difference between Groups I and III, and an *F* of 3.245 for the difference between Groups II and III. An *F*, based on groups containing eight subjects (thus having seven degrees of freedom), is significant at the 5% level if it equals or

variability (as well as in the means) of their conditioning scores.

This finding might be interpreted as meaning that the animals constituting Groups I, II, and III were not assigned to these groups on the basis of a truly random selection. Since there is, however, no empirical reason for believing that this was the case, the more plausible alternative is the assumption that the three different experimental procedures which were employed resulted, not only

in differences in average incidence of conditioning, but also in differences in "individual differences." This latter supposition is further supported by Figure 5. Here it will be noted that the trial-to-trial variability manifested by Group II is conspicuously lower than that manifested by the other two groups. It is true that this kind of variability is not the same as individual-difference variability;

critical-ratio technique (otherwise indicated here) presupposes that the variations from trial to trial are normally distributed. From inspection this appears not to be the case; but since the differences in variability are so striking inspectionally, there is no urgent need for a statistical estimate of their reliabilities.

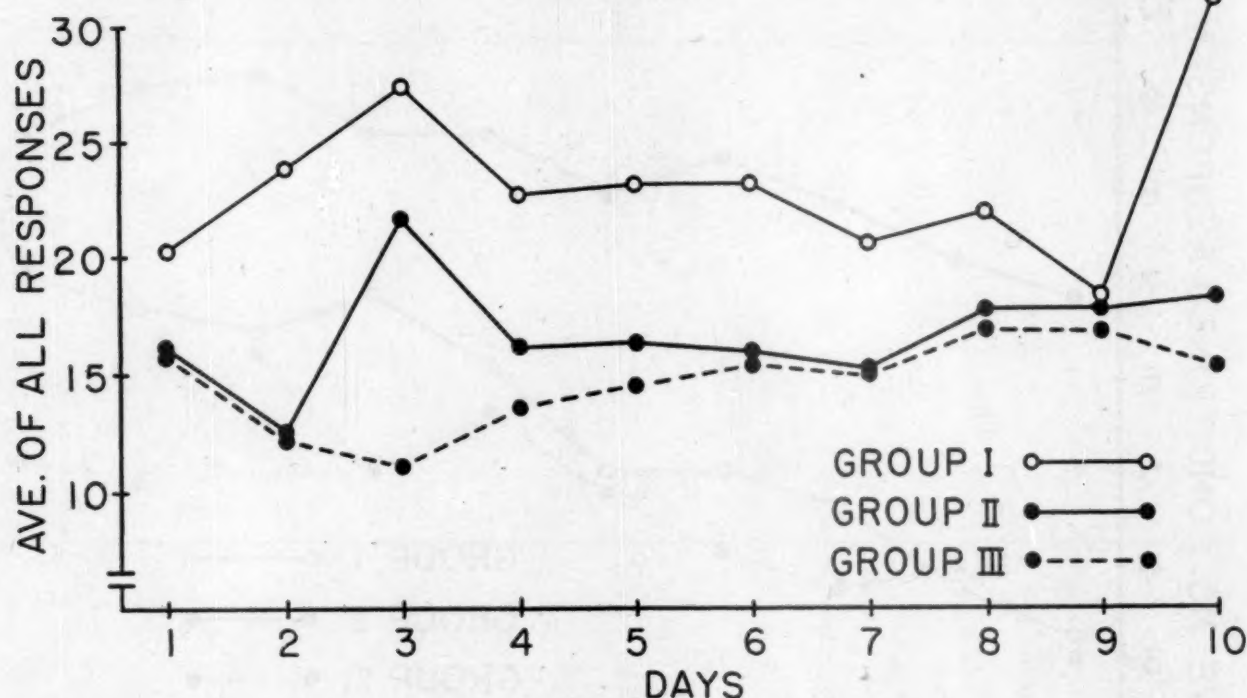Although the group differences in the variability of conditioning obtained in

Fig. 7. Average number of responses (conditioned, unconditioned, and "spontaneous") made by Groups I, II, and III on each of the 10 successive days of the experiment. Since the average number of conditioned plus unconditioned responses was always 10 per day, the number of "spontaneous" responses alone can be determined by regarding 10 on the ordinate of the graph as the baseline. The sudden rise in the Group-I curve on the 10th day was caused by a single animal and does not, therefore, represent a general trend.

but since Group II ranks lowest in both respects, a presumption is established that the experimental conditions under which the three groups of animals were tested actually influence not only the average amount of conditioning but also the factor of variability, as reflected by both indices.

No attempt has been made to establish the statistical reliability of the differences in the trial-to-trial variability of the three groups, since the use of the

this investigation were not predicted, they can be explained in a manner consistent with the general theoretical position outlined in the introduction, as will be shown later.

From Figure 5, it is evident that not only was there a day-to-day increment in the number of conditioned responses made by the various groups (see Figure 4) but that there was also a trial-to-trial increment. In order to make this latter phenomenon more obvious, the average

number of conditioned responses made by all animals in each of the three groups on each of the 10 trials given on each day are presented in Figure 5b. As might have been expected, this arrangement of the data again shows the Group-II animals to be markedly superior to the Group-I and Group-III animals, with the former slightly better than the latter. Since these curves are based on the same data as are the curves presented in Figure 4, the reliabilities of the differences between them are the same as those between the curves in Figure 4.

Number of "Spontaneous" Responses

The three curves shown in Figure 7 represent the averages of all responses, including conditioned, unconditioned, and "spontaneous," made on the 10 successive days of experimentation by the animals in Groups I, II, and III. Since each animal necessarily made a combined total of 10 conditioned and unconditioned responses during each daily session of 10 trials, the average number of "spontaneous" responses can be readily ascertained by deducting 10 from each of the values represented in Figure 7. In other words, if the point which is labeled "10" on the ordinate of the graph is taken as the baseline, the respective curves then represent the number of "spontaneous" responses made on the successive days by each group. When computed by the method described in the preceding section, the critical ratio of the difference in spontaneous responses made by Groups I and II is found to be 1.960, by Groups I and III, 2.848, and by Groups II and III, 1.188. According to Fisher's "Table of t," these critical ratios are significant at the 10%, 2%, and 30% levels respectively. The values ("spontaneous" responses only) from which these critical ratios were

derived are: for Group I, 14, 16, 107, 107, 157, 191, 226, 239; for Group II, 18, 26, 28, 50, 76, 91, 96, 158; and for Group III, 4, 20, 41, 52, 52, 54, 64, 87. Although the range of scores in the three groups differs considerably,[24] the coefficients of variability are relatively constant, being 66.44 for Group I, 69.41 for Group II, and 54.00 for Group III. Since these values are so nearly the same, it seemed scarcely worth while applying a z-test to them; for all practical purposes the differences between them can be assumed to be non-significant.

Noteworthy is the fact that the number of "spontaneous" responses made by the three groups of subjects do not correspond in any direct manner to the incidence of conditioned responses in the three groups. Whereas Group II, for example, is highest in conditioned responses, it is intermediate in spontaneous responses. This finding shows that the higher incidence of conditioning in Group II was not due to a higher level of general activity. In fact, when the rank-order correlation between conditioned responses and spontaneous responses is computed for all animals used in the whole experiment, an r of $-.13$ is obtained, which is non-significant. When, however, the correlations between conditioned and "spontaneous" responses within each of the three groups are computed, an r of $+.59$ is obtained for Group I, $+.47$ for Group II, and $+.78$ for Group III. Since the number of subjects in each group is comparatively small, these values are not very reliable, but they probably indicate a real trend for conditioned and "spontaneous" responses to be positively correlated *within*

[24] It is also striking how large the range is in all groups in relation to the mean. In other words, the individual differences in respect to number of "spontaneous" responses is, for some reason, unusually great.
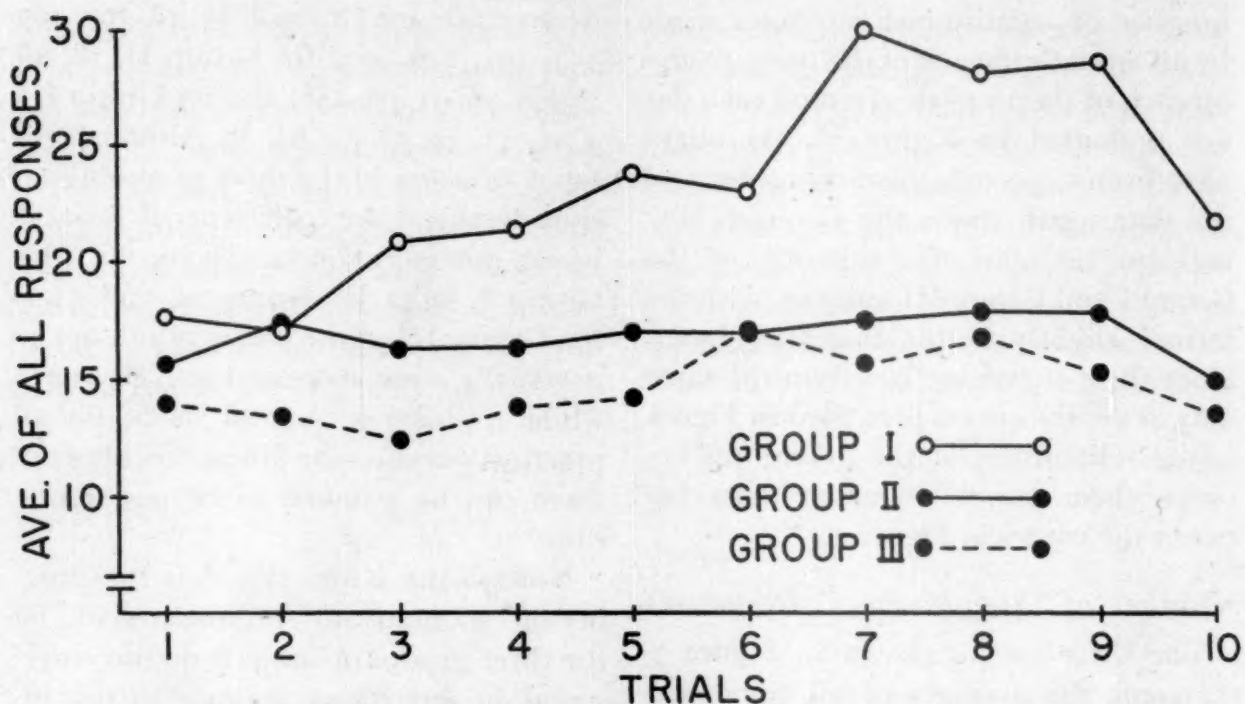
FIG. 8. Average number of responses (conditioned, unconditioned, and "spontaneous") made by Groups I, II, and III on trials 1-10 on all 10 days of the experiment.
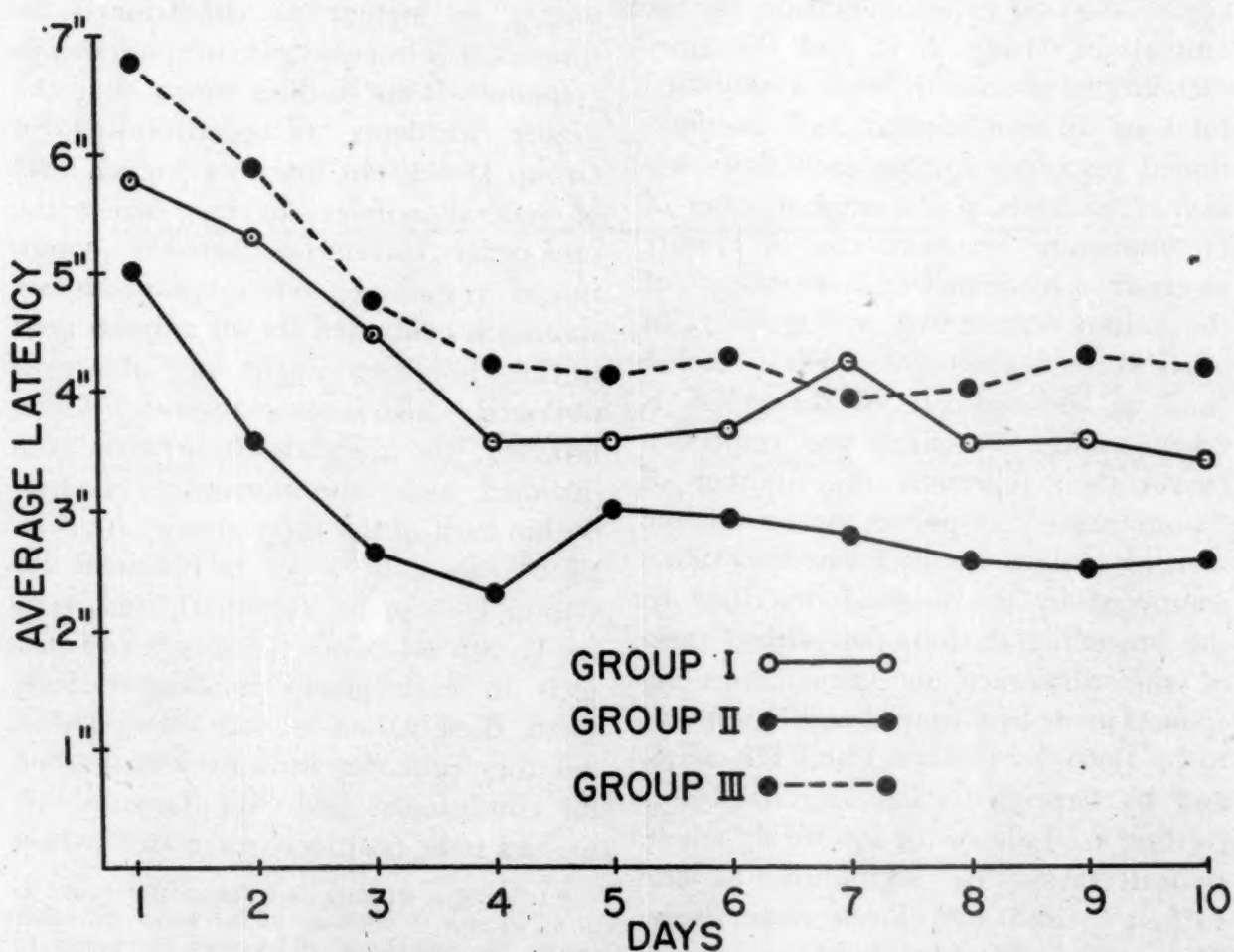

FIG. 9. Average latency, by days, between onset of the conditioned stimulus and the occurrence of either a conditioned or an unconditioned response.

groups. Reasons why they are not correlated *between* groups will be considered in a later section, as will the meaning of the word "spontaneous" as used in the present context.

In Figure 7 there is no very clear-cut trend in the amount of "spontaneous" activity observed from day to day. When these responses are analyzed, as they are points at which "spontaneous" responses occurred during the two-minute intervals between trials, the latencies of all conditioned and all unconditioned responses, with respect to the onset of the conditioned stimulus, were timed to within 0.1 second. The daily averages of these values for Groups I, II, and III are represented in the three curves shown in
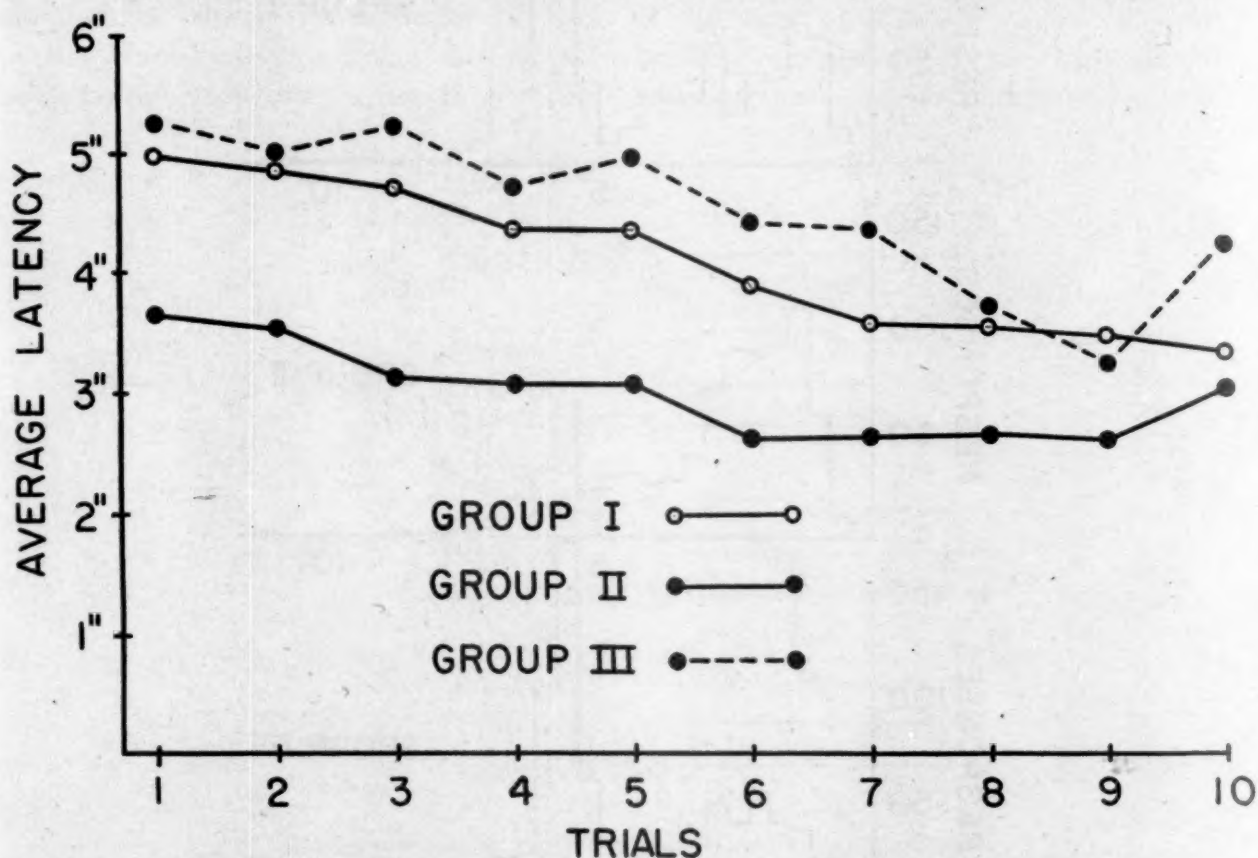

FIG. 10. Average latency, by trials on all days, between onset of the conditioned stimulus and the occurrence of either a conditioned or an unconditioned response.

in Figure 8, on the basis of their average incidence on each trial within the 10 different daily sessions, Group II and III again show no particular trend, although Group I shows a marked upward trend. An explanation of this latter phenomenon will be suggested later. Since the same basic data were employed, the reliabilities of the differences between the three curves in Figure 8 are the same as in Figure 7.

Response Latencies

Although no record was kept of the Figure 9. As might have been expected, the Group-II animals showed consistently shorter latencies than did either the Group-I or the Group-III animals. Not only do the latency curves reflect the same over-all superiority of the Group-II procedure as do the conditioned-response curves: they inversely parallel them almost exactly. If Figure 4 is inverted and held in front of a mirror, the resemblance to Figure 9 is striking indeed, extending even to the coincidence of the points at which the curves for Groups I and III cross each other. Response latency and

incidence of conditioned responses may be said, therefore, to be more or less equivalent measures of the same phenomenon, at least as far as the present

10 are obtained. Here again there is a marked resemblance to the conditioned-response curves shown in Figure 5, although the correspondence is not quite
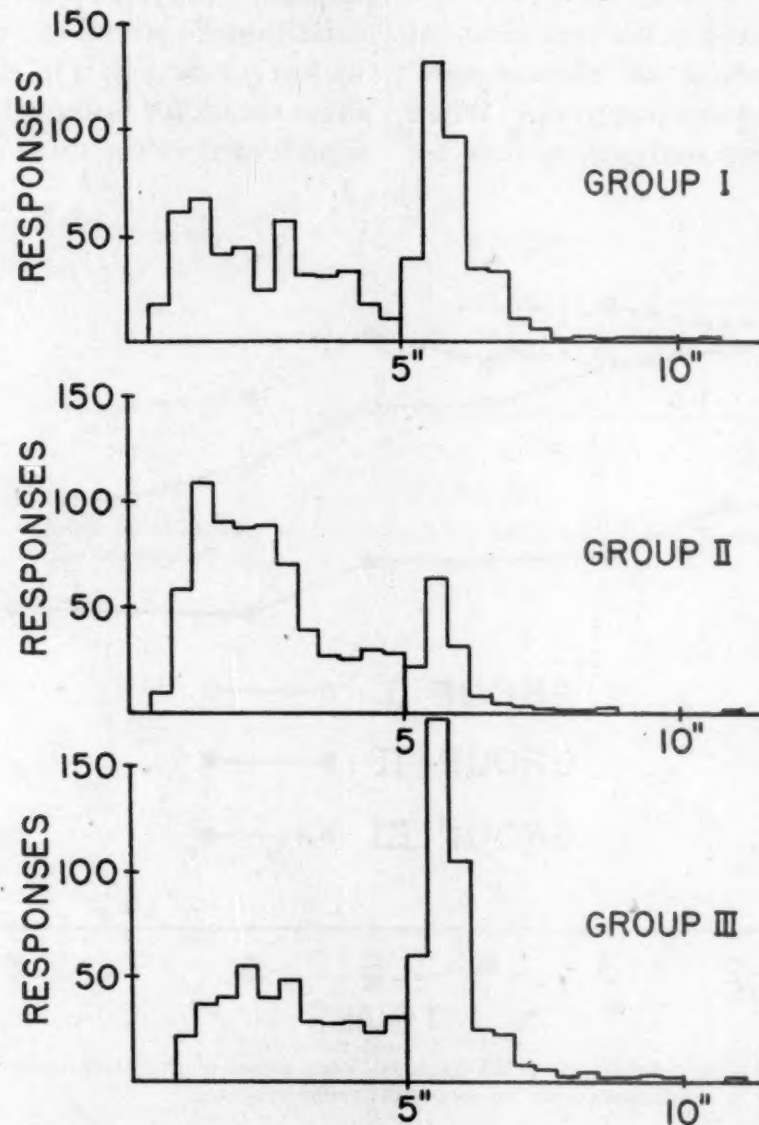

FIG. 11. Histographic representation of the number of conditioned responses (within 5″) and the number of unconditioned responses (after 5″) occurring at various step intervals after onset of the conditioned stimulus. In Group I there were three unconditioned responses with latencies too long to be represented here (16.0″, 17.8″, 18.0″). In Group III there were five such responses (16.0″, 19.8″, 14.6″, 35.6″, 13.2″).

type of experimental situation is concerned. This is not, however, surprising when it is remembered that the criterion of a conditioned response is a temporal one.

When the latency data are arranged by trials, the curves presented in Figure

so close as between the curves in Figure 4 and Figure 9. Although all three curves in Figure 10 show a substantial over-all decrement from trials 1-10, it must be realized that this is a composite picture of what happened throughout the experiment. On the first three or four days,

when learning was most rapid (see Figure 9), there was also the greatest trial-to-trial latency decrement. During the latter part of the experiment, there was comparatively little change, both as regards day-to-day and trial-to-trial performances. If the experiment had been continued for another 10 days, it is conceivable that a point would have been reached at which the latencies of the earlier responses on a given day might have become actually shorter than those

overview of the results of the experiment as a whole are the three histograms represented in Figure 11. These show the number of responses which occurred in Groups I, II, and III at various step intervals (0.0-0.3", 0.4-0.7", 0.8-1.1" 1.2-1.5", etc.) after the onset of the conditioned stimulus. By virtue of the practice, common to all group procedures, of allowing an interval of five seconds between the onset of the conditioned stimulus and the unconditioned stimu-
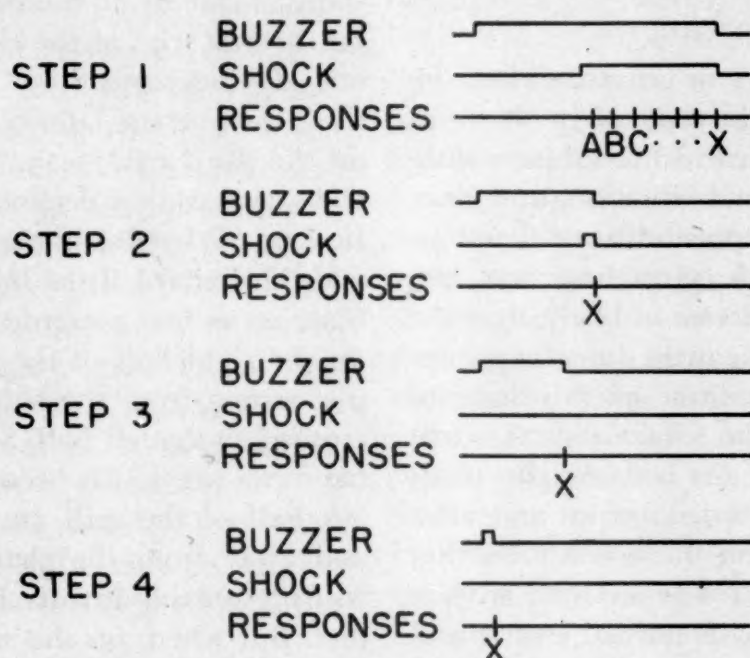

FIG. 12. Schematic representation of the relation between trial-and-error learning and conditioning.

of the later responses on that day, due to the absence of further learning and the operation of opposing forces such as fatigue, loss of emotional tension, or the like.

Although it would have been readily possible to compute critical ratios of the differences between the averages of the latency data presented in Figures 9 and 10, this did not seem called for inasmuch as the earlier analysis of the conditioned-response data had already shown a satisfactory differentiation between Group II and Groups I and III.

Of especial value in providing an

lus, all responses which occurred within this interval are conditioned responses and all those which occurred afterwards are unconditioned responses. These histograms show not only the greater incidence of conditioned responses in Group II but also reveal the group differences in response-latencies just described. Due to the greater incidence of conditioned responses in Group II, the average latency of all conditioned and all unconditioned responses (800 in all) made by this group was only 2.99", as against 4.11" for Group I and 4.6" for Group

III. The latencies of the conditioned responses alone was 2.40″, 2.40″, and 2.83″ for Groups I, II, and III respectively. The average latencies for the unconditioned responses made by the three groups were, in order, 6.28″, 6.00″, and 6.29″. Although the Group-II procedure thus seems to be somewhat superior as regards both conditioned- and unconditioned-response latencies, its major advantage lies in the greater incidence of conditioned responses which it produces.

Miscellaneous Findings

Since the present investigation involved the production of a state of anxiety on the part of the subjects within the experimental situation, and since the adjustmental possibilities differed according to which procedure was employed, it seemed not unlikely that the animals used in the three different groups might give indications of this state of affairs outside the experimental situation. Accordingly, the body-weights of all subjects were recorded before and after the experiment, on the assumption that any tendency toward generalized anxiety might interfere with normal eating and assimilation. No significant weight change was found in any of the three groups. Group-I and Group-III animals seemed to show more anxiety, as revealed by urination and defecation, within the experimental situation, but no systematic records were kept of this behavior.

As previously mentioned, of the eight animals used in each of the three experimental groups, seven were females and one was a male. As it turned out, the male in each group made the smallest number of conditioned responses. Since the likelihood that this outcome was merely a coincidence was very small, it was at first supposed that it might represent a true sex difference in emotionality; but what now seems more probable is that since the males were considerably larger than the females, the shock which they received was less painful (due to smaller current density) and that they accordingly showed less conditioning, because of weaker motivation. This explanation is, however, conjectural. The problem deserves being investigated systematically.

One other incidental finding is worth noting. The average latency of the response made by all animals in all groups on the first trial of the experiment (trial one, day one) was 6.15.″ On the second trial, the average latency was 6.39,″ and on the third trial, 6.45.″ On succeeding trials, this average declines. But the question is: "Why did it rise on the second and third trials? If the buzzer-shock combination is first presented when a rat is on the right half of the grill, for example, escape from the shock involves his crossing to the left half. Since the animal has never previously been shocked on the left half of the grill, moving toward it and away from the charged right half will presumably involve little or no conflict. But when, on the second trial, the left half of the grill is electrified, the adjustive response consists of returning to the right half, where the rat has been shocked only a little while before. The conflict arising on this second trial presumably accounts for the increase in average latency from 6.15″ on the first trial to 6.39″ on the second. This type of conflict seems to disappear rapidly as training proceeds and interferes surprisingly little with the efficiency of the general conditioning procedure. It should be remembered, however, that a two-minute interval was always allowed between trials; a briefer trial-to-trial interval would almost certainly cause this conflict to be more pronounced.

DISCUSSION

Interpretation in Terms of Anxiety—Reduction

The results of this study confirm the prediction that better avoidance conditioning will take place if the conditioned stimulus, or "danger signal", terminates with, rather than either before or after, the conditioned response.[25] Such a confirmation strengthens the hypothesis from which the prediction was derived, namely, that *once a conditioned response has developed on the basis of "parasitic" reinforcement, it tends to be independently reinforced and perpetuated, providing that it terminates the danger signal and thereby reduces the subject's attendant anxiety.* In other words, a response which results in the *avoidance* of a primary (unconditioned) noxious stimulus may continue to occur to the appropriate danger signal for a long time, without further "parasitic" reinforcement, because *its occurrence provides escape from a secondary form of noxious stimulation, namely, fear.* Since fear, however painful it may be, will not kill an organism,[26] whereas the thing feared may do so, it is as if nature has provided this surrogate motive and source of reinforcement as a means of perpetuating responses which serve to keep the organism from re-experiencing the original, potentially fatal motive.

This interpretation squares with a number of observations which are not easily explained by the traditional associationistic theory of conditioning. A number of years ago Lashley (27) found in experiments on conditioned finger withdrawal in which respiration and heart rate were concurrently recorded that the withdrawal responses continued only so long as the visceral indices of fear continued to be elicited by the conditioned stimulus. When the conditioned stimulus ceased to produce emotional upset, the overt finger response quickly disappeared. This finding substantiates the hypothesis that the conditioned avoidance response is fear-motivated and will continue to resist extinction, in the absence of parasitic reinforcement, only so long as it continues to receive reinforcement through fear-reduction.[27] Naturally such a response may have some "momentum", or "reserve", derived from past reinforcements, but this can be counted on to perpetuate the response for only a few elicitations if the secondary reinforcement here described does not occur.

That fear is intimately related to the perpetuation of conditioned avoidance response is likewise indicated by the observation, described by Hamel (17) and confirmed by others, that such a

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[25] Since the above was written, personal correspondence received from Professor Elmer Culler reveals that in unpublished experimentation he, too, has found that a variable conditioned stimulus gives better results than does one of fixed duration. He says: "My own observation confirms what you say, that the animal conditions more quickly and seems in general more alert and responsive if the sound is turned off at the instant of response; in other words, if the animal gets rid of the sound by reacting to it. I have made use of this method a good many times in conditioning animals myself; I thus agree that the animal works best when he is given opportunity to learn both that his response terminates the shock, and also that his response terminates the sound which signals or symbolizes the oncoming shock." Cf. also Parmenter (41) on the use of a variable conditioned stimulus in producing extinction.

[26] In making this statement it is realized, of course, that if fear becomes too intense and can be reduced in no other way, suicide may be resorted to. Chronic anxiety states may also result indirectly in death by creating gastro-intestinal, cardiac, and other "functional" disturbances which eventually produce genuine organic pathology. But these facts are not inconsistent with the thesis that fear is, in general, less harmful biologically than the thing feared.

[27] Another interesting fact, reported by various investigators (17, 48, 49) is that visceral disturbances always seem to be conditioned first, before overt avoidance responses develop.

response is more readily established and maintained if a strong rather than a weak unconditioned stimulus is used. On the basis of classical association theory, conditioning should result merely from the paired presentation of two stimuli, providing only that the second stimulus is barely strong enough to elicit the desired response. Intensity of the unconditioned stimulus beyond this point should have no significance, yet it patently does. On the basis of the hypothesis here proposed, there are two reasons why avoidance conditioning is positively related to the intensity of the unconditioned stimulus. The more intense this stimulus is the greater will be both the intrinsic and the parasitic reinforcement produced by its termination. And since the fear response (itself a product of parasitic reinforcement) is proportional to the intensity of the trauma which the danger signal pressages, then the second-order reinforcement provided by fear reduction will be positively related to the intensity of the unconditioned stimulus.

Considerable discussion has taken place in recent years as to why it is that the conditioned response nearly always differs in detail from the so-called unconditioned response and may even be quite radically different. An example of the latter type is the difference between the behavior of a man whose house is actually on fire and the behavior of the same man if he is merely apprehensive lest his house should catch afire. On the basis of classical associationism, i.e., simple stimulus-substitutionism, one would expect all conditioned responses to be more or less exact replicas of unconditioned responses. The present hypothesis, on the contrary, provides for quite a different possibility. Just as any response which reduces a primary motive will become more and more strongly connected

with that motive, so will any response which reduces a secondary motive likewise become more and more strongly connected with that motive. In the present investigation, it so happened that the same response that reduced shock also reduced the secondary motive of fear, by terminating the conditioned stimulus; but other responses not infrequently occurred while the buzzer was sounding, and if any one of these had been systematically followed by buzzer termination, it would very probably have been learned.[28] It is true that by the mechanism of parasitic reinforcement, the same response which reduced the unconditioned stimulus tends to become specifically connected with the conditioned stimulus; but, as already shown, parasitic reinforcement is not the only mechanism which is operative in avoidance conditioning.

That fear is the common denominator in all avoidance conditioning situations is indicated, first of all, by the observation reported by Liddell, James and Anderson (28), and by others, that extinguished avoidance response can usually be revived by one or two presentations of the unconditioned stimulus alone. This reinstates apprehension and fear, and as a result the avoidance response returns without further paired presentation. The point is similarly made by the finding of Finch and Culler (9) and of Brogden (5) that once an avoidance response is established, it can be kept going under threat of shock administered at anatomical loci very remote from the point of application of the shock employed in the original conditioning. It also seems probable, if it has not indeed already been demonstrated, that a conditioned avoidance response, if it re-

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[28] Subsequent experimentation by the writers has confirmed this inference.

duces the danger signal, could likewise be perpetuated indefinitely if the *nature*, as well as the locus, of the noxious stimulus were changed. That is to say, if a conditioned response were established with electric shock as the unconditioned stimulus, this response could probably be kept permanently alive under threat of the subject's being beaten, burned, or pained in any of various other ways.[29]

Especially pointed in this connection are the comparative data reported by Brogden (4) on the resistance to extinction of the same response, which was acquired in the case of one group of dogs as a means of securing food and in another group as a means of escaping (and avoiding) shock. This writer summarizes his results by saying that "conditioned flexion [of a dog's left forelimb] originally reënforced with shock [reduction] will persist without reinforcement after a lapse of 6 months, over thrice as long as will conditioned flexion originally reënforced with food [hunger reduction]" (p. 287). Although Brogden inclines to the view that the passage of time is responsible for the differential resistance to extinction in the two cases, the hypothesis here proposed would explain this discrepancy as due to the fact that extinction of a hunger-motivated response starts as soon as the response ceases to result in hunger-reduction, whereas a fear-motivated response may continue to be reinforced through fear-reduction long after the situation has changed so that the conditioned stimulus will no longer be followed by the unconditioned stimulus if the conditioned response does not occur, i.e., after the

danger signal ceases to signify real, objective danger. It is instructive that all instances of so-called "failure of extinction" reviewed by Hilgard and Marquis (19) involve responses of the avoidant type. That all instances of "repetition compulsions" and of "functional autonomy" involve subtle sources of anxiety-reduction also seems likely but cannot be fully demonstrated on the basis of available data.

The preceding discussion involves an assumption which has not been made explicit up to this point, namely, that fear, as a form of motivation which is itself due to a conditioned visceral reaction (19, 33, 50), is easier to establish and harder to extinguish than are conditioned skeletal responses. Clinical as well as experimental observations support this assumption but do not explain the underlying mechanics of the difference. That the fear response may be biologically very useful as a means of converting a weak but highly significant stimulus (danger signal) into a powerful motive, capable of eliciting and sustaining the most vigorous and varied behavior, is evident; but why it is that this "amplification" system is so exceptionally sensitive and efficient, in comparison with other conditioned responses, requires independent investigation.

Other Hypotheses Examined

As pointed out at the beginning of this section, the experimental findings of the present study confirm the prediction that if a conditioned avoidance response terminates the danger signal, it will persist longer, without parasitic reinforcement, than if the danger signal is of arbitrarily fixed duration. Although empirical confirmation of a prediction strengthens the hypothesis from which it is derived, the same prediction can often

[29] See also studies by Miller (31) and by Mowrer (36) demonstrating the reinforcing value of anxiety-reduction, as distinct from reinforcement derived from the paired presentation of conditioned and unconditioned stimuli.

be made on the basis of other hypotheses. In the present instance there are at least three such hypotheses, which will be examined and evaluated in turn.

1. Pavlov (42) and his students have shown that if a conditioned stimulus terminates well before food is presented to a hungry dog, a less vigorous conditioned salivary response is established than if the conditioned stimulus lasts until the food appears. The former procedure has been termed "trace conditioning" and is superficially parallel to the Group-I procedure employed in the present investigation. On the basis of the demonstrated inferiority of trace conditioning of the Pavlovian type, the Group-I animals in the present study might have been expected to make a comparatively poor showing. There are, however, two salient differences between the Pavlovian situation and the one here employed. In the first place, Pavlov was using a training procedure in which the emotional reaction to the conditioned stimulus was appetite rather than anxiety; termination of the conditioned stimulus would therefore be expected to have different functions in the two cases. Furthermore, Pavlov used the classical conditioning procedure, whereas the present writers employed the instrumental procedure. Even if the instrumental procedure were used in both types of situations, an important difference would remain in that in the one instance the so-called unconditioned stimulus (food) would be omitted if the conditioned response did not occur, while in the other instance the unconditioned stimulus (shock) would be omitted if the conditioned response did occur.[30] These considerations make it extremely hazardous to interpret the findings of the present investigation in terms of Pavlov's observations and theories.

It could likewise be maintained on the basis of Pavlovian researches that the inferior conditioning obtained in the Group-III animals was due to extinction, adaptation, or the like, which was occasioned by the fact that the conditioned stimulus always lasted for five seconds after the conditioned (or unconditioned) response occurred. So far as the writers are aware, no experiment has ever been carried out in which the conditioned stimulus has been continued for a fixed interval after the presentation of food in the Pavlovian type of situation; but they predict that the results of such a procedure would not be very different from the results secured by the usual procedure of terminating the conditioned stimulus when food is presented. Instead of trying to interpret the findings of the present investigation in terms of Pavlovian theory, it might be more profitable to examine Pavlovian findings in the light of present theory. This will not be attempted at this time, but the prediction is made that a salivary conditioning procedure, patterned after the Group-II procedure here described, in which food would be presented as soon as the conditioned response occurs and withheld if the conditioned response does not occur within a standard period of time, will give better results than usually

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[30] To describe both food and shock as unconditioned stimuli is to illustrate the looseness and ambiguity with which the concept of the unconditioned stimulus has been used. If one is to be consistent about the matter, the unconditioned stimulus in the Pavlovian situation must be defined as sight of food *plus hunger*. Since food alone will not make a satiated animal eat and since hunger alone, in the absence of food, likewise does not elicit eating reactions, the response to food plus hunger is clearly a *patterned*, or discriminative, reaction which has itself been learned. In the case of avoidance conditioning, on the other hand, the response to the so-called unconditioned stimulus is not in this sense also patterned.

obtained by the Pavlovian procedure, and that the troublesome phenomenon of "inhibition of reinforcement" would be entirely averted.

2. Another alternative interpretation of our results is that the buzzer which served as the conditioned stimulus was so loud that its termination was intrinsically rewarding, quite aside from any anxiety-reduction that might have been involved. If this were the case, it would follow that a procedure in which the buzzer terminated at the instant that the conditioned response occurred would perpetuate a conditioned response better than a procedure in which the conditioned stimulus ended either significantly before or after the conditioned response. It has been shown elsewhere (39) that if conditioned stimuli of varying intensities are employed with the Group-II type of procedure, an intense conditioned stimulus produces better conditioning than does a weaker one. It may be, therefore, that part of the differentiation between the Group-II results and those for Groups I and III was a function of the intrinsic reward value of buzzer termination. There are, however, other facts which make it unlikely that this is the sole, if even a partial explanation of this differentiation.

In unpublished experimentation by the senior author it was found very difficult, if not impossible, to teach rats to perform any specific response as a means of terminating a sound which was far more intense than the one used in the present investigation as the conditioned stimulus. Moreover, if the intrinsic rewarding function of buzzer termination were marked, extinction in the Group-II procedure would never occur, which has been shown in an independent study by the writers not to be the case. Finally, if buzzer termination had an intrinsically powerful rewarding, or reinforcing effect, the buzzer would be expected to have proportionately great potency as a motive. Although it must not be supposed that the buzzer had no motivational properties in its own right, these seem to have been comparatively trivial since, as Figures 7 and 8 show, Group I, for which buzzer duration was briefest, displayed the greatest number of "spontaneous" responses, whereas Group III, for which buzzer duration was greatest, showed the fewest "spontaneous" responses. Group II, for which buzzer duration was intermediate, showed an intermediate number of such responses. There is thus an inverse relation between "spontaneous" response and buzzer duration, which is opposite to what would be expected if the buzzer were a powerful motive in its own right.[31]

3. It is also conceivable that the Group-II procedure proved superior because of the so-called Law of Emphasis, or Vividness. It is true that in Group II the "emphasis" conjecturally created by buzzer termination coincided with the occurrence of the conditioned responses, while in Groups I and III it did not. The results may, therefore, be said to be consistent with the "emphasis" hypothesis. Whether it is actually the "emphasis" factor or anxiety reduction which accounts for the superiority of the Group-II procedure could presumably be determined by substituting for buzzer termination, as the hypothetical "emphasizer," a flash of light or some similar distinctive stimulus which would not have however, any particular value as a "safety" signal. The writers predict that such a stimulus would not materially affect the incidence of conditioning.[32]

[31] Cf. Lamoreaux and Mowrer (26).
[32] Professor D. P. Boder, of Lewis Institute, Chicago, has expressed to the writers an intention of carrying out an experiment of this kind.

Some Incidental Considerations

Turning to the incidental findings of this investigation, it is noteworthy, first of all, that there was a relatively large positive correlation between the incidence of conditioned responses and the number of spontaneous responses made between trials in each group, considered separately, although there was no such correlation when all groups were considered together. How can this outcome be explained? The solution seems to hinge upon the fact that in the present investigation there were two distinct sources of so-called spontaneous responses. Every student of conditioning knows that if a noxious stimulus is repeatedly presented at regular intervals, with or without an accompanying signal, subjects almost invariably show "temporal conditioning", i.e., they remain relatively inactive for a time immediately after each stimulation but then begin, as the time for the next stimulation approaches, to make, with increasing frequency, the response which is under investigation (along with other unrecorded responses) (35). The greater this tendency to make spontaneous, or anticipatory, responses on the basis of temporal conditioning, the greater the likelihood that the conditioned stimulus proper will elicit a response.[33] This observation probably explains why it is that with condi-

tioning procedure held constant, the subjects in the present investigation showed positive correlations between conditioning and spontaneous activity.

When, however, the conditioning procedure was varied, as it was in the three different groups, a new factor enters into the picture. It will be recalled that in the Group-I procedure, the buzzer was sounded for only one second, with four seconds of grace intervening before the shock occurred. This meant that in those instances in which a conditioned response did not occur and the shock was presented, there was, in a manner of speaking, two stimuli which preceded the shock—buzzer and silence. Both therefore, became dangerous and tended to elicit running (as well as other) responses.[34] Since a running response was counted as conditioned only if it occurred within five seconds after the onset of the buzzer and since silence persisted indefinitely, one can see why the animals in this group, being more or less "left up in the air", made many responses which would necessarily be counted as "spontaneous." The Group-II and Group-III animals, on the other hand, were never shocked after the buzzer had quit sounding; for them, therefore, silence was safe instead of dangerous. They would consequently be expected to show comparatively few spontaneous responses, in keeping with the observed facts. Since the Group-I animals made the greatest number of spontaneous responses and made relatively few conditioned responses, one sees why the overall correlation between these two types of reaction was nil, even though it was relatively high in all three groups, consid-

[33] Pavlov (42), Hull (24), and others have pointed out that temporal conditioning must be based upon some intraorganismic process, or neural reverberation, set going by preceding stimulation. This "stimulus trace," when it reaches the appropriate point (determined by the rate of previous stimulations), tends, in a way not yet understood, to elicit the response in question. Seemingly correct in principle but incomplete, this interpretation overlooks the fact that the first conditioning in a situation of this kind involves visceral reactions (48, 49) which are concomitants of anxiety. Once anxiety occurs, it may be that so-called spontaneous responses are produced by it rather than by the stimulus trace alone.

[34] The more technically exact characterization of the situation would be to say that both the buzzer and its "trace" preceded the shock and therefore became danger signals.

ered separately.[35]

In the preceding discussion the assumption has repeatedly been made that, given appropriate conditions, anxiety results in agitated, restless behavior. The symptoms of common "nervousness" obviously support this supposition; but it is a no less familiar observation that anxiety may also inhibit or paralyze action. Why fear, or anxiety, has sometimes the one effect and at other times exactly the opposite one is a problem that has occasioned much speculation but now appears readily solvable, Whether fear results in agitation and flight or in frozen

inaction seems to be primarily, if not exclusively, a function of the locus of the danger signal. If the danger signal is an *external* one, such as the buzzer employed in the present investigation, the resulting anxiety is almost certain to produce activity, since such behavior, if it carries the organism away from the danger situation or eliminates the danger signal in some other way, is more or less powerfully reinforced by anxiety-reduction. On the other hand, if the danger signal is *internal,* consisting of proprioceptive stimuli produced by a previously "punished" response, then the resulting anxiety is equally likely to inhibit activity, since this is the most direct means of eliminating the danger signal and thereby reducing anxiety. The hypothesis that anxiety-reduction reinforces whatever type of behavior accomplishes this end thus proves a unifying principle, explaining why it is that anxiety produced by "prodding," on the one hand, and by "punishment," on the other hand, have such unlike effects.[36]

Conditioning as Problem Solving

Comparatively few writers on the subject have explicitly regarded conditioning as a type of "problem solving." One obvious reason for this is that so long as a classical conditioning procedure is employed, no real solution to the problem thereby created is in fact possible.[37] There are, however, numerous advan-

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[35] These observations raise an incidental problem of very considerable interest. If, as in the Group-I procedure, a danger signal terminates before the affected organism has had time to make the appropriate reaction, how is the organism to "know" when it is safe? The fact that the Group-I animals made the greatest number of "spontaneous" responses suggests that they were indeed somewhat "insecure," or "nervous," i.e., were uncertain as to when they were in danger and when they were not. The animals were not, however, entirely without cues in this situation. Since the shock, if it occurred, always came four seconds after the buzzer (which lasted one second) had ceased, this point on the stimulus trace of the buzzer represented the region of "maximum danger," and later points on the trace became progressively less ominous. But even if the shock had occurred (in the event of no conditioned response) at highly irregular intervals after the buzzer had ended, there would still have been a means of determining when the shock had been averted and when it had not. Since the stimulus trace of the buzzer and the stimulus trace of the avoidant response would *never precede* the shock, then this combination would mean *safety*, as opposed to the *danger* implied by the buzzer trace alone. In short, as soon as the animal learned to *discriminate* between buzzer trace alone and buzzer trace *plus* response trace, it would "know" when it was safe and when it was not. Thus, even though conditions were such that there was no change in the *external* stimulus situation when the right response had been made, an animal could eventually learn, on the basis of *internal* cues, to feel rewarded (freed from anxiety) when it had behaved "properly." This analysis would appear to take us near an explanation (cf. the psychoanalytic conception) of certain forms of "compulsive" behavior seen in human beings and is suggestive of a way in which the notion of "conscience" as "internalized authority" can be made more concrete and objective (Cf. also footnote 19).

[36] From this it follows that if an organism is being "prodded" but at the same time "punished" for every attempted adjustment to the first source of discomfort, persistent anxiety will result. Such a state seems to be a prelude to all neuroses.

[37] Cf. experiment by Brogden, Lipman, and Culler which was described in the introductory section. See also Girden (15), Hunter (25) and Woodworth (51). In personal correspondence, Professor H. S. Liddell has likewise expressed the conviction that classical conditioning procedure is "biologically senseless."

tages in taking a functional—some might miscall it a teleological—view of conditioning. Some of these advantages have already been indicated. Two others remain to be discussed.

In the investigation here reported, all subjects actually faced, as is always true in conditioning situations involving a noxious unconditioned stimulus, two problems rather than only one. The first of these was the problem created by the occurrence of the electric shock. The solution to this problem consisted of the animal's running to the opposite end of the apparatus. Some learning was involved in perfecting this simple adjustment; but since running in response to noxious stimulation of the feet has almost inevitably received some previous reinforcement, this response is likely to be relatively high in the initial hierarchy of responses made by rats to shock. Such learning as is involved at this level of adjustment is therefore likely to occur very rapidly.

The other problem which the subjects in this study had to face was that created by the anxiety caused by the danger signal. Anxiety, like shock, is also a noxious stimulus, or drive, and similarly demands adjustive action. The solution to this second-order type of problem was very easy of attainment in the Group-II procedure, consisting of the same response as that required to shock, namely, merely running to the opposite end of the apparatus. This response immediately eliminated the danger signal and was reinforced, presumably, by marked anxiety-reduction. In the Group-I and Group-III procedures, on the other hand, no such ideal solution was available. It is true that if, in either case, an animal responded to the danger signal within five seconds after its onset, the animal avoided shock; but as already

pointed out, such a response was not accompanied by buzzer-termination and anxiety-reduction. In other words, in both the Group-I and Group-III procedures the best possible solution to the problem created by the buzzer-induced anxiety was distinctly inferior to the solution that was possible in the Group-II procedure. It is almost axiomatic, therefore, that the incidence of conditioned responses in these two relatively unfavorable procedures should have been significantly lower than in the optimal Group-II procedure.

This line of analysis leads to an explanation of the finding that the Group-I and Group-III animals showed not only less conditioning but also greater variability than did the Group-II animals, both as regards "individual differences" for the experiment as a whole and trial-to-trial group performances (see Figure 5). When one views the problem created by the buzzer in the three groups in terms of the goodness of adjustment (to anxiety) which was possible, it becomes understandable that the procedure which provided the best possibility of adjustment (Group II) should have produced least variability. If an organism has found a good solution to a problem, it is much less likely to continue "searching" for a better one than is an organism that has found a less good solution or none at all. In other words, since exploratory behavior plays so large a role in the adjustmental process, the continuation of response variation in the latter type of situation is clearly an advantage biologically. As Dodge (7) has pointed out and Boring (1) re-emphasized, we have been too long content to regard behavior variability as a statistical rather than as a psychological problem. The connection between this phenomenon and what may be called goodness of

adjustment is patent but needs to be investigated in detail.

Of particular interest from a systematic point of view is the fact that by regarding conditioning as a kind of second-order problem-solving behavior, it can be brought into an orderly relationship to so-called trial-and-error learning, or "simple" problem solving. This relationship is schematically represented in Figure 12. Originally (Step 1) the buzzer does not "mean" danger to the rat and elicits no response of any interest (to the experimenter). When the shock occurs, it produces various responses, A, B, C . . . X happens to be the "correct" (shock-reducing) response, consisting in this instance of running to the opposite end of the apparatus. After a few repetitions, X *moves forward*—or *upward,* if one wishes to preserve the hierarchical conceptualization—and occurs without delay or intervention of other responses, when the shock is presented (Step 2). This "coming forward" is, of course, the phenomenon ordinarily designated as trial-and-error learning and is based upon the mechanism of "intrinsic" (shock-reduction) reinforcement mentioned above. But while this first-order type of learning has been going on, something else has been happening, i.e., a connection has been developing, not only between the shock and X, but also (by "parasitic" reinforcement) between the buzzer and X. Under the ideal conditions provided by the Group-II procedure, it is usually only a matter of a few more trials after the shock-X connection has become prompt and specific until the buzzer-X connection becomes strong enough for the buzzer alone to elicit X (Step 3). When this happens, a conditioned response is said to have occurred. In other words, the response, X has continued its forward march and has become anticipatory, or

avoidant, with respect to the shock. If, as in the Group-II procedure, the conditioned response immediately terminates the buzzer, it has a tendency to move forward still further and to occur the instant that the buzzer is sounded (Step 4). Trial-and-error learning and conditioning thus become merely different aspects of, or stages in, a single, continuous adjustive process.[38,39]

This continuity between trial-and-error learning and conditioning has been generally overlooked, or ignored, in the past largely for the reason that most investigators have concerned themselves more or less exclusively with only one of these phenomena. Both must be studied, preferably simultaneously, if their complementary, inter-related character is to be observed and understood.

The distinction which Pavlov (42) and his followers have made between unconditioned and conditioned responses was adumbrated by Sherrington (45), in 1906, who proposed a functional division of behavior into *consummatory* responses and *anticipatory* responses. Although useful as a first approximation, this

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[38] This is not to say, however, that trial-and-error learning and conditioning are synonymous, as some writers currently assume. In fact, systematic completeness demands that a third form of learning be interposed between them, namely, pattern learning. Thus, given appropriate conditions, a rat will learn to make one habitual response to shock plus buzzer and a different response to shock plus bell. Pattern learning is related to, if not identical with, discrimination and configurational phenomena in general. According to the present schema, all three forms of learning involve the principle of reinforcement through drive, or tension-reduction.

[39] The schematization shown in Figure 12 is deliberately incomplete (for sake of simplicity) in that it shows X as the only response occurring to the buzzer. As indicated earlier, a conditioned stimulus almost always elicits many responses other than the one which the experimenter is specifically prepared to observe and record. In a situation of the kind under discussion, the conditioned stimulus always produces more or less anxiety, which may then produce a wide variety of reactions in its own right.

dichotomy is not entirely satisfactory for the reason that a response which is anticipatory with respect to one type of problem (drive) may be consummatory with respect to another. Thus, in the present study a conditioned response made under the Group-II procedure is indeed anticipatory, or avoidant, with respect to the shock; but it is consummatory with respect to the anxiety created by the buzzer.[40] This fact provides a partial explanation of how it is that so much behavior gives the illusion of being either teleological (caused by events that have not yet occurred) or "functionally autonomous" (persisting without motivation and reward). In the Group-II procedure, which seems fairly to typify those situations in which avoidance conditioning most commonly and efficiently occurs in nature, shock-avoidance is reinforced and perpetuated by anxiety-reduction. The shock, without occurring, does indeed seem to influence the animal's behavior; but this relationship is only apparent. As already shown, the animal's behavior can be entirely accounted for in terms of the danger-signal, ensuing anxiety, and anxiety-reduction, without any reference to the shock, except to the extent that its *past* occurrence in conjunction with the danger signal is responsible for the development of the anxiety reaction and for the parasitic reinforcement which initially brings the avoidance response into existence.

Although no empirical data are reported in this study concerning extinction, the hypothesis supported by the results which are here described generates certain definite expectations concerning extinction. On the basis of this

[40] Another difficulty arises in trying to determine, in a series of instrumental acts such as those involved in running a maze, which responses are anticipatory and which consummatory.

hypothesis, one would predict that if three groups of subjects were all conditioned by the same procedure, i.e., by either the Group-I, Group-II, or Group-III procedure, and were then submitted, respectively, to extinction involving each of these three procedures, marked differences in resistance to extinction would be found, corresponding to the effectiveness which the three procedures have in producing conditioning. This prediction can be easily tested and, if confirmed, would provide further substantiation of the general point of view here advanced.

There is a growing body of evidence that extinction depends upon the existance of an unfavorable balance between the fatigue (stimulation increase) generated by an act and the amount of reward (stimulation decrease) thereby attained. This hypothesis provides an explanation of why it is that massing of trials accelerates extinction and retards acquisition (36). Carried a step further, this analysis leads to another prediction. In any situation in which anxiety is the chief motive, anxiety-reduction (reward) is a function, among other things, of the rate at which the danger signal is presented (39). From this it follows that massing of trials would be even more effective in producing extinction and in retarding acquisition in the case of avoidance conditioning than in other forms of conditioning. Further investigation will be required to determine whether this is actually true.

So-called "spinal conditioning" is one of the few phenomena which do not readily fit into the theory of avoidance conditioning here advanced. Since the autonomic nervous system is presumably disconnected in a spinal-conditioning preparation from the caudal segment of the central nervous system in which conditioning occurs, it is unlikely that anx-

iety can play any role in learning of this kind. This (plus the sparsity of association centers outside the brain) may account for the fact that spinal and other forms of subcortical conditioning are, as Pavlov has shown (42), ordinarily so difficult to be obtained. That spinal conditioning can occur at all may conceivably be due entirely to the parasitic reinforcement produced by termination of the unconditioned stimulus.

SUMMARY

Earlier experimentation has shown that the "instrumental" conditioning procedure gives results which are dramatically superior to those obtained by the "classical" conditioning procedure in situations in which the unconditioned stimulus is an electrical shock or similar noxious event. Analysis of the reasons for this difference leads to the deduction that the "instrumental" procedure should give even better results if modified so that the conditioned stimulus, or "danger signal", terminates at the moment that the conditioned response occurs, instead of lasting for an arbitrarily fixed period of time.

This deduction is tested with three groups of rats in which the conditioned stimulus regularly terminates before (Group I), with (Group II), and after (Group III) the conditioned response. The fact that the second of these procedures gives conspicuously better conditioning than either of the other two is taken as confirmation of the hypothesis from which the deduction was derived. This hypothesis, in brief, is that *a conditioned avoidance response develops on the basis of "parasitic" reinforcement but is independently perpetuated, under favorable conditions, by the reinforcement resulting from the anxiety-reduction which accompanies termination of the conditioned stimulus.* Possible alternative interpretations of the obtained results are evaluated and differential predictions made.

The Group-II procedure was found to give not only better conditioning but also less variability. If conditioning, like trial-and-error learning, is seen as an adjustive process, this finding becomes intelligible since variability would be expected to be inversely correlated with the goodness of the adjustment which any particular conditioning procedure makes possible.

Although there are pronounced group differences in the number of "spontaneous" responses made between trials, there is no over-all correlation between such responses and conditioning. This finding negates the otherwise possible inference that the greater number of conditioned responses made by the Group-II animals was due merely to a greater tendency toward agitated behavior. The fact that there is, however, a sizeable positive correlation between these two phenomena within each of the three groups is discussed and an explanation proposed.

The latencies of both the conditioned and the unconditioned responses made by the animals in all three groups were recorded and analyzed. These data again show the Group-II procedure to be markedly superior to the other two and lead to a further discussion of the continuity between trial-and-error learning and conditioning.

The position is taken that no comprehensive theory of avoidance conditioning is possible without taking the concomitant phenomenon of anxiety and its role as a reinforcing agent into systematic account. When this is done, numerous problems, which have been perpetual paradoxes from the point of view of

associationism, become readily solvable. Some of the questions considered in this connection are:

a). Why do conditioned skeletal responses of an avoidant nature soon disappear when the conditioned stimulus ceases to produce visceral disturbances?

b). Why is avoidance conditioning proportional to the intensity of the unconditioned noxious stimulus?

c). Why are avoidance responses often very different from the responses made to the so-called unconditioned stimulus?

d). Why can an avoidance response be perpetuated by dangers very different from the one involved in the original conditioning situation?

e). Why are avoidance responses more resistant to extinction than are other conditioned responses?

f). Why does behavior sometimes seem to be "teleological" or "functionally autonomous"?

g). Why does "classical" conditioning result in "inhibition of reinforcement"?

h). Is the "massing of practice" more influential in determining avoidance conditioning and extinction than in determining other kinds of learning?

i). Why does anxiety sometimes produce activity and at other times inhibit activity?

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